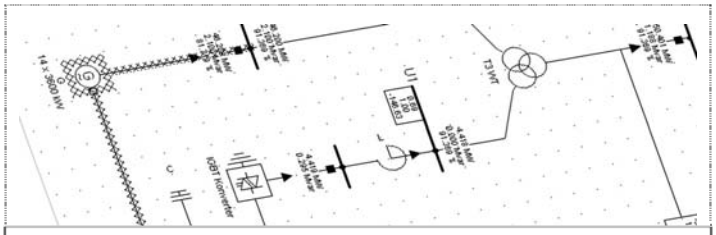

DIgSILENT
Technical Documentation

# How To
# Use the New Features of
# *PowerFactory* Version 14.0

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**How To Use the New Features of PowerFactory Version 14.0**

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# 1 Introduction

This paper will give you a description of the most important new features in ***PowerFactory*** **Version 14.0**. For more detailed information please refer to the User's Manual.

# 2 The PowerFactory V14 Standard Data Model

## 2.1 General Arrangement of Data in the Project Folder

To understand the structure of the 'project folder' it is useful to examine which kind of information is represented by the data and what it is used for. This will direct us to the data model of ***PowerFactory***. Figure 2.1 shows the new data arrangement.

In Version 14 all changes in the projects are tracked: the date (day and time) of changing and the user who did the changing are stored inside the data base.

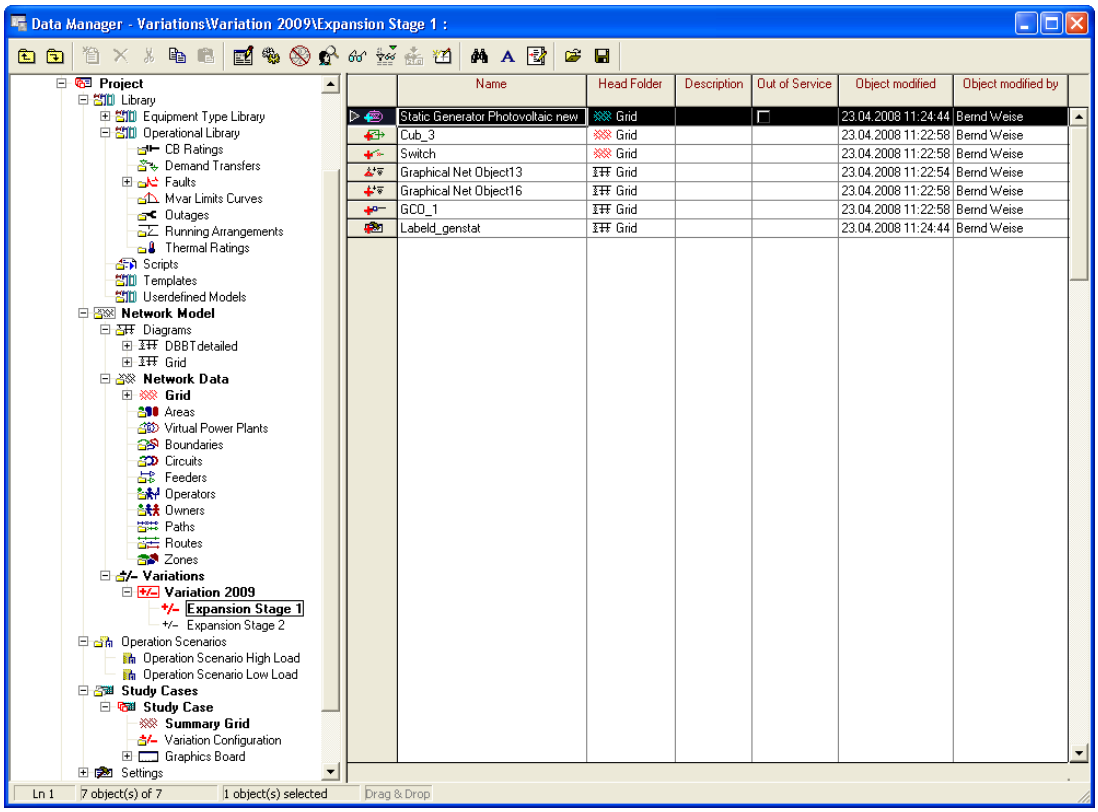


Figure 2.1: Data Arrangement in the Data Manager

## 2.1.1 The Library

The library contains the equipment types (like in older versions of ***PowerFactory***), special operational informations, DPL scripts, templates and user-defined models.

To make the library well arranged, in ***PowerFactory*** Version 14 the equipment types are stored in a special subfolder called "Equipment Type Library".

### 2.1.1.1 Equipment Type Library

We would like to store all the manufacturer data in the same place and organize it in such a way that it can be easily accessed when defining the power system elements. Within the data model this information corresponds to the type data.

An equipment type object holds the essential electrical information for each class of network component. This information is usually provided in manufacture's data sheets. Within the project structure the type objects are stored inside the Equipment Type Library. Type objects may be sorted by class using library subfolders, e. g. a subfolder for generator types, a subfolder for line types etc.

### 2.1.1.2 Operational Library

Frequently we would like to change the operation point of the network, in order to analyze the effect of different load levels, maintenances or operative limits. An Operational Library folder, sorting all the possible operational alternatives, is part of the approach used by ***PowerFactory*** to optimize this task.

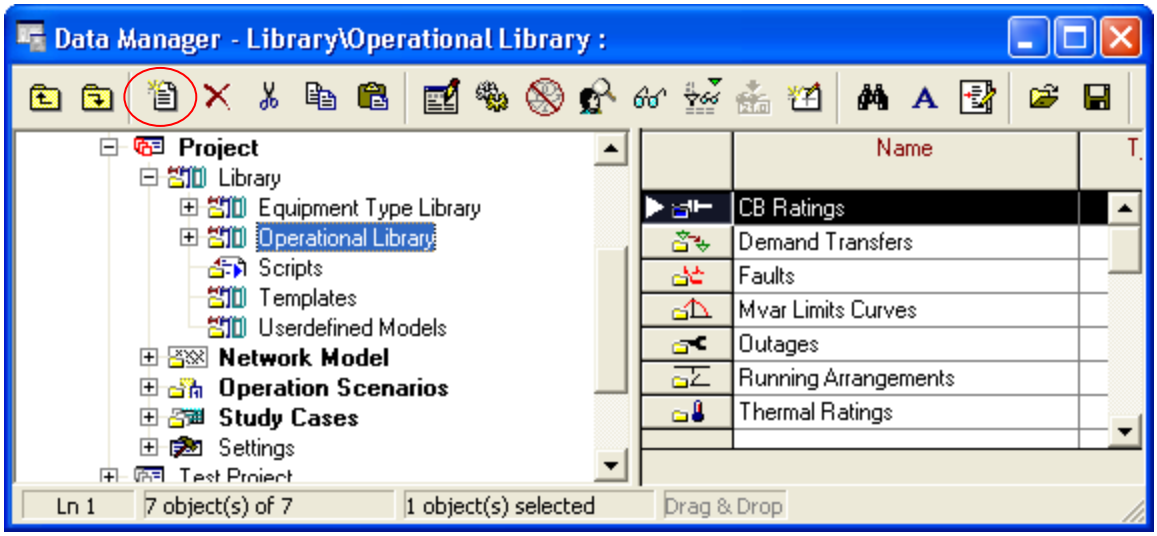


***Figure 2.2: Operational Library***

To create a new element in each of these folders, first select the folder by clicking once on it. Then press the "New Object" button, and choose from the selection the element you want to create.

## 2.1.2 The Network Model

The Network Model contains the electrical and graphical information of the grid. To improve the general survey, these information is split into two folders now: **Diagrams** and **Network Data**. In an additional folder **Variations** all expansion stages for planning purposes are stored. Together with the so-called Operation Scenario the Variations substitute the previous concept of system stages.

### 2.1.2.1 Network Data

The electrical data may be sorted according to logical or organizational and/ or geographical areas; consequently several **Grid** folders stored together within the **Network Data** folder are defined.

### 2.1.2.2 Diagrams

When you draw a grid, all graphic information will be stored in this folder automatically.

### 2.1.2.3 Variations

In order to plan or assess the network under different topology configurations, we would like to be able to create variations of the current network. It would be useful if these variations are linked to the original data, so that changes made in the original network are automatically transferred to the variation. Additionally these variations should be placed in a time frame, in order to allow scheduled expansion plans. ***PowerFactory*** uses objects called **Expansion Stages** to model such time dependant variations. Expansion stages are stored inside so-called **Variation** objects. Variations can be seen as expansion plans composed of different expansion stages, which are chronologically activated. Variations, like all other network data, are stored inside the Network Model folder. Expansion Stages (of an active Variation) are activated automatically by ***PowerFactory***, if you set the date and time of the calculation case to a value, which is equal to or higher than the **Activation Time** of the expansion stage.

This concept of variations and expansion stages is complemented by Operation Scenarios, which are stored on the same level like the network model, because these scenarios don't model the grid itself, but its operation.

## 2.1.3 Operation Scenarios

Storing recurrent operation points and being able to activate or deactivate them when required, accelerates the analyses of the network under different operative conditions, e.g. different dispatch programs, low or high load periods, etc. ***PowerFactory*** can store complete operation points in objects called operation scenarios. These kind of data, which is subject to frequent changes during a study and may be used to simulate different operation scenarios of the same network, is further grouped in subsets. Within the project folder, operation scenarios are stored inside the **Operation Scenarios** folder.

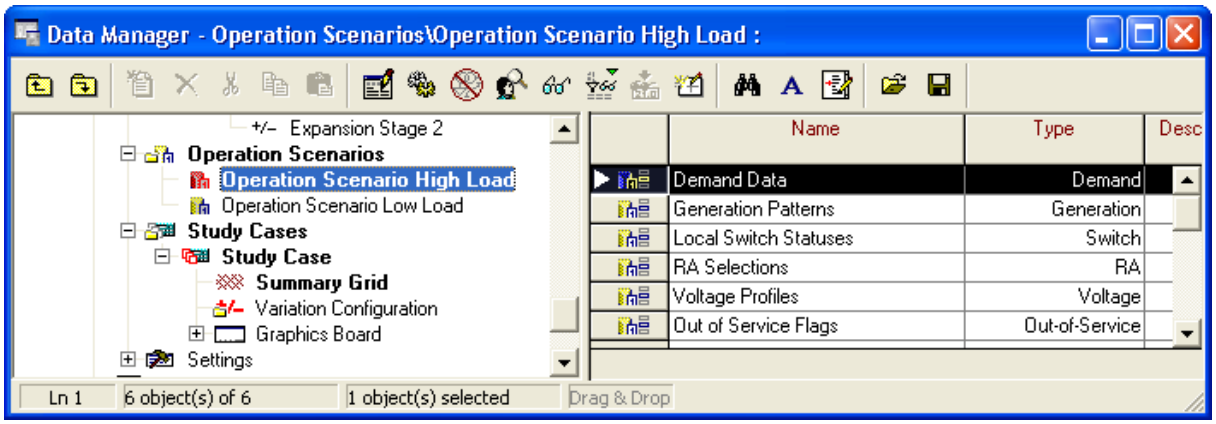


***Figure 2.3: Operation Scenarios***

We may need to analyze the network at different times during the day, week or year, where different load conditions and ratings of the components are considered. As described above, Operational Library objects and Operation Scenarios allow this feature by defining different operation points. An additional tool called **Parameter Characteristics** was designed to facilitate, even more, this considerations. By means of characteristics a range of values, instead of a fixed amount, is assigned to the parameters of power systems elements. Within the range, the selection of the appropriate value for the parameter is carried out according to a user defined trigger. For example the active power demand of a load can be modeled by means of a characteristic with 12 values, each one corresponding to a month of the year. If the trigger is set to January (triggers are defined by the user), then the value taken by the program to perform the calculations will be the first value of the characteristic, if the trigger is set to December, the last value of the characteristic will be assumed.

## 2.1.4 Study Cases

Once the network data has been entered and set, we will want to perform various studies, for example, load-flow, various short-circuits, time dependant simulations, etc. It would be useful if the results of these studies could also be stored for review or repeated later. The concept of the Study Case is the same as it was in previous versions of ***PowerFactory***. In version 14 all study cases are stored inside a folder called **Study Cases** to make the project folder well arranged.

## 2.2 Study Time

PowerFactory V14 extends the idea of a model into the dimension of time. The model may span a period of months or even years considering network expansions, planned outages and other system events. The period of validy of a project specifies therefore the time span the model is valid for. If you want to use this functionality, you have to define the Validity Period of a project. The Study Case has got a Study Time, which has to be inside the Validity Period of the Project.

The Study Time defines the point in time you wish to analyse. ***PowerFactory*** will use the Study Time in conjunction with time-dependent network expansions (variations, expansion stages, see chapter 2.3.2) to determine which network data is applicable to that point in time. You are able to change the Study Time in order to analyse a different point in time. The Expansion Stages will be activated/deactivated with the Study Time.

To specify the Study Time:

- Press the button "Date/Time of Calculation Case" in the main toolbar of PowerFactory.
- Enter the date and time or press the button -> Date and -> Time in order to set the Study Time to the current time of your computer.
- Press **OK** to accept the changes and close the window.

Alternatively:

- Activate the project and browse for the Study Case in the Data Manager.
- Right click on the Study Case and select Edit from the context sensitive menu.
- On the Basic Data tab page press the button with the three dots beneath the entry for the Study Time
- Set the Study Time according to your needs.
- Press **OK** to accept the changes and close the window.

To specify the Validity Period of the Project:

- Open the Data Manager and browse for the Project folder object (IntPrj).
- Right click on it and select *Edit* from the context sensitive menu.
- On the Basic Data tab press the 'Project Settings' Edit button (the button with the blue right arrow). The Project Settings dialogue will open.
- On the "Validity Period" page adjust the start and end time of the project.
- Press **OK** to accept the changes and close the window.

# 2.3 The Network Model

As introduced in section 2.1.2, the Network Model folder contains the set of graphical and electrical data that defines the networks and the single line diagrams of the studied power system. This set of data is going to be referred as the network data model. The following folders are defined inside the Network Model:

- **Network Diagrams**
  Contains all the objects with the graphical information (single line diagrams) from the networks defined in the project.

- **Network Data**
  Contains all the network components of the power system: generators, busbars, transformers, lines, switches, controller models, etc.

- **Variations**
  This folder contains the objects representing variations of the defined networks like topological changes, installation or retirement of network components, etc. You can set time stamps of the variations on order to make them time dependant.

## 2.3.1 Network Topology Handling

### 2.3.1.1 Nodes

In circuit theory, the junction points connecting lines, generators, loads, etc. to the network are generally called nodes. In ***PowerFactory*** nodes are modeled by means of objects called 'Terminals' (ElmTerm). Depending on their usage within the power system, terminals can be the representation of busbars, junctions or simply internal nodes (the usage is defined in a drop down menu found in the 'Basic Data' tab of the terminal dialogue). According to this selected usage different calculation functions would be enabled; for example the short circuit calculation can be performed just for Busbars or for Busbars and Internal nodes, etc.

When any branch element is directly connected to a terminal, ***PowerFactory*** uses what is known as a 'Cubicle' (StaCubic) to carry out this connection. Cubicles may be visualized as the panels in a switchgear board, or bays in a high voltage yard, to which the branch elements are connected.

### 2.3.1.2 Branch Elements

As explained before branch elements are connected to the nodes by means of cubicles. A connection between two nodes is carried out by two-port elements like transformers, switches or lines. Three port elements require a connection to three different nodes.

In the general case the branch elements are single components whose connection to the network is automatically set when indicating the connected terminal. From the data model point of view, the case of transmission lines (and cables) is interesting, because they can be defined as a one-to-one connection between two nodes or as folders containing line sections that together connect two nodes.

### 2.3.1.3 Substations

Detailed representations of electrical substations can be achieved in ***PowerFactory*** by connecting and storing terminals and switches together, under the same 'Substation' object (ElmSubstat). Substations can be used to model composite busbar systems, by storing terminal and switches arrangements under the same object. Separate single line diagrams of individual substations can be created. Substation objects allow the use of running arrangements to store/set a certain status of the station circuit breakers (ElmCoup objects).

**Defining Substations in the Data Manager**

A description of the procedure used to define new substations with the data manager is given as follows. For information about working with substations in the graphical editor please refer to section 2.4.

To define a new substation from the Data Manager do the following:

- Display the content of the grid where you want to create the new substation.
- Right click on the right pane of the Data Manager and select 'New -> Substation' from the context sensitive menu.
- The new substation edit dialogue will pop up. There you can change the name, assign running arrangements and visualize/edit the content of the substation (directly after creation it is empty).
- After pressing Ok the new substation and an associated diagram (with the same name of the substation) will be created.

The components of the new substation can be created and connected using the associated single line diagram or using the data manager, the first option is recommended. For the second option, a data browser with the content of the substation will pop up after pressing the Contents button; there you can use the New Object icon to create the new components.

Components of a substation can of course be connected with components of the corresponding grid or even with components of other networks. The connection in the Data Manager is carried out following the same procedure discussed in the previous section.

### 2.3.1.4 Branches

Similar to substations, ***PowerFactory*** allows the storing of nodes and branch elements under the same object (Branch object ElmBranch) in order to represent branched-off connections between two terminals or substations. Branches are 'composite' two port elements that may be connected at each end to a node. One typical application is a distribution line with branched off loads along the connection: transmission lines, loads and the corresponding terminals can be stored together under the same branch, the two ends of the line correspond to the branch connections with the grid. As in the case of Substations, separate single line graphics for branches can be created with the graphical editor.

Next a description of the procedure used to define new branches from the data manager is given. For information about working with branches in the graphical editor please refer to section 2.4.

To define a new branch from the Data Manager do the following:

- Display the content of the grid where you want to create the new substation.
- Right click on the right pane of the Data Manager and select New --> Branch from the context sensitive menu.
- The new branch edit dialogue will pop up. There you can define the name of the new branch and a circuit to which the branch belongs. The fields 'Connection 1' and 'Connection 2' define the branch elements that are going to be connected with external elements. Once the user has defined the internal branch elements, he/she can access and change the connecting components (i. e. the components referred in 'Connection 1' and 'Connection 2').
- After pressing Ok the new branch and an associated diagram (with the same name of the branch) will be created.

The components of the new branch can be created and connected using the associated single line diagram or using the data manager, the first option is recommended. For the second option, a data browser with the content of the branch will pop up after pressing the Contents button; there you can use the New Object icon to create the new components.

Components of a branch can of course be connected with components of the corresponding grid or even with components of other networks (remember that the maximal number of connections for a branch is 2). Once the external connections of the branch have been established, the user can use the 'Jump' button on the edit dialogue to open the edit dialogue of the grid elements connected to it.

### 2.3.1.5 Sites

Substations, Branches and any other network component can be stored together under the same 'Site' object in order to represent and analyze a network by geographical (topological) regions. Sites are high hierarchical level objects that can store any defined component within a network.

**Defining Sites in the Data Manager**

Next a description of the procedure used to define new sites is given. To define a new site from the Data Manager do the following:

- Display the content of the grid where you want to create the new site.
- Right click on the right pane of the Data Manager and select 'New → Site' from the context sensitive menu.
- The new Site edit dialogue will pop up.
- After pressing Ok the new site will be created.

### 2.3.1.6 Boundaries

Boundaries are objects used in the definition of network reductions and in summation reports after a load flow calculation (to report the active and reactive power flow along the boundary). Boundary objects (ElmBoundary) may define topological regions by specifying a topological cut through the network.

New boundaries are created by specifying the cubicles that define the cut through the network. An interior region, corresponding to the boundary cut, is defined by specifying a direction for each cubicle. Interior regions and boundaries can be colored in the single line graphic.

New boundaries are stored in the Boundaries folder within the Network Data folder. Boundaries themselves are defined by a user selected set of cubicles, the terminals connected to them and a selected orientation.

The cubicles in the boundary element define a cut through the network, that together with the orientations are used to define the corresponding "Interior Region". Topologically, the interior region is found searching through the network starting at each selected cubicles towards the given direction. The topological search continues until either an open switch or a cubicle that is part of the boundary list is found. Any open switch that is found by this search is considered to be part of the interior region.

To define a new Boundary you have to multi select in the single line diagram a set of cubicles and terminals, which will define the boundary, and then to select in the context sensitive menu (right click) Define… --> Boundary…. The dialogue of the new Boundary will pop up. By pressing Ok the new object is created in the Boundaries folder of the Network Model.

To add cubicles to an existing Boundary:

- In the Boundary dialogue, right click on the table (on the number of a row) that lists the included cubicles.
- Select *Insert rows*, *Append rows* or *Append n rows* from the context sensitive menu.
- Double click on the Boundary Points cell of the new line.
- Select the target cubicle using the data browser that pops up.
- After selecting the desired cubicle, the terminal and the branch element connected to it are added to the 'Terminal' and 'Components' cells on the table. By default the 'Orientation' (direction used to determine the interior region) is set to the branch; you can change it in order to direct the definition of the internal region to the connected terminal.

Cubicles can be retired from a Boundary by selecting 'Delete rows' from the context sensitive menu of the table in the element dialogue.

The selected color at the bottom of the dialogue is used to represent the boundary in the single line diagrams. Each element in the graphic is colored according to the following criteria:

- If it uniquely belongs to one interior region of a boundary to be drawn, its color will be assigned to that specific boundary color.

- If it belongs to exactly two of the interior regions of the boundaries to be drawn, its will be represented with dashed lines in the specific boundary colors.

- If it belongs to exactly more than two of the interior regions of the boundaries to be drawn, its will be represented with dashed lines in black and the color selected for multiple intersections.

The Edit Interior Elements button can be used to list in a data browser all the components included in the internal region. The Mark Interior Region button marks all the components of the interior region in the selected network diagram. Topological changes in the network that affect the defined interior regions are automatically detected by the program.

### 2.3.1.7 Circuits

Circuits are objects of the class ElmCircuit, used to group branches in order to make clear which branches are connected galvanically. Each branch (ElmBranch) can have a reference to any defined Circuit object. This feature allows the sorting of branches according to the circuit they belong to.

To create a new Circuit:

- In the Data Manager open the Circuits folder from the Network Model.

- Click on the New Object icon.

- The edit dialogue of the new Circuit pops up. Give a name to the new object and press Ok.

Branches are added to a circuit using the pointer from the 'Circuit' field of the branch dialogue. The button *Branches* in the Circuit dialogue opens a data browser listing the branches that refer to that circuit.

### 2.3.1.8 Routes

Routes are objects used to group line couplings (tower elements). Each coupling (ElmTow) can have a reference to any defined route (ElmRoute). Each route has a color that can be used to identify it in the single line diagrams, when the corresponding coloring function is enabled.

### 2.3.1.9 Operators

For descriptive purposes it is useful to sort network components according to their operators. Also for system operators it may result advantageous to generate summary reports of the losses, generation, load, etc. on their operated regions. ***PowerFactory*** allows the definition of operators, the assignment of network components to them and their identification on the single line diagrams by means of the so called Operator objects.

The Operator objects (ElmOperator) are stored in the 'Operators' folder of the Network Data directory.

#### 2.3.1.10 Owners

For descriptive purposes it is useful to sort network components according to their owners. Also for network owners it may result advantageous to generate summary reports of the losses, generation, load, etc. on their owned regions. Similar to Operators, ***PowerFactory*** allows the definition of network owners and the assignment of network components to them, by means of the so called Owner objects.

The Owner objects (ElmOwner) are stored in the 'Owners' folder of the Network Data directory.

## 2.3.2 Variations

During the planning and assessment of a power system it is necessary to analyze different variations and expansion alternatives of the original networks. In ***PowerFactory*** this variations are modeled by means of the so called 'Variations', which are objects that can store and implement the changes expected on a network without affecting the original model. The use of variations allows the realization of studies under different network configuration in an organized and simple way. The user only needs to define (by means of Variations) the changes that she/he wants to implement and then activate or deactivate them according to her/his studies.

Different variations can be independently applied (activated) at the same time to the same network, facilitating even more the work of the analyst. The changes can also be implemented gradually according to the study time, in order to allow the representation of scheduled expansion plans.

Variations objects (IntVariation) are stored inside the 'Variations' folder under the Network Model directory. Variations are composed of "expansion stages" (IntSstage), that store the changes on the original networks. The application of the changes depends on the current study time and the activation time of the expansion stages.

The study time is a parameter of the active study case, used to situate the current study within a time frame. The activation time is a parameter given to the expansion stages, in order to determine, according to the study time, if the contained changes are applied or not. If the activation time proceeds the study time, the changes are applied to the original network. The changes of a subsequent expansion stage add to the changes of its predecessors.

A variation must be activated, so that the changes in the network configuration contained in its stages are carried out. Once the variation is deactivated, the network returns to its original state. The changes contained in a expansion stage can be classified as:

- Parameter changes of the network components.
- Adding changes, new objects added to the actual network.
- Deleting changes.

### 2.3.2.1 Creating Variations and Expansion stages

It might be necessary to make topological changes in the network model for a study. Use of *variations* makes sure that these changes are recorded separately, and that the original network remains intact. A variation object is created in the "Variations" folder under the "Network Model" folder as shown in Figure 2.4.

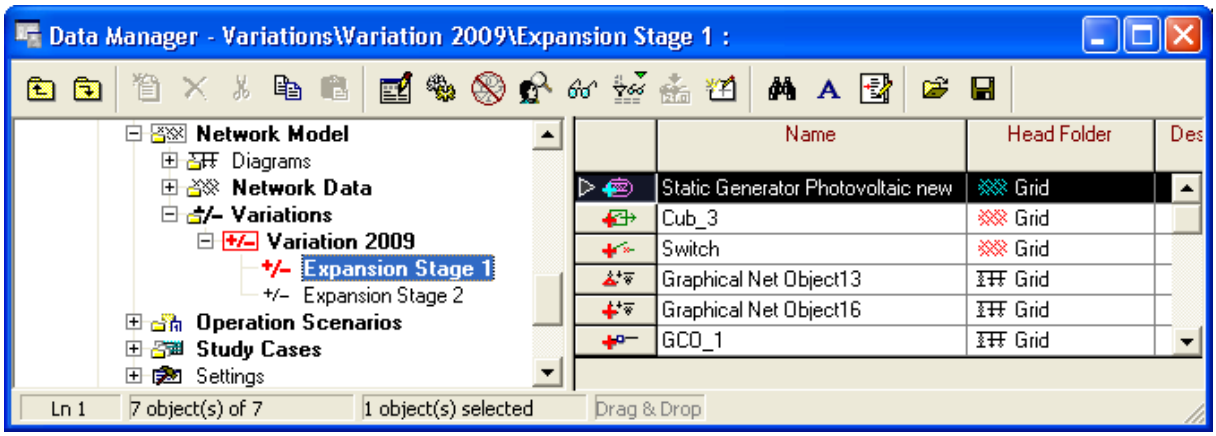


***Figure 2.4: Variations folder with Expansion Stages***

To create a variation right-click on the Variations folder ( ) in the data manager, and select New -> Variation from the context sensitive menu. Alternatively, select the Variations folder,click on the "New Object" button ( ) on the icon bar of the Data Manager. Make sure the "Element" field is set to "Variation (IntVariation)" and press OK. The dialogue of the new variation pops up.

In the variation dialogue you can edit the name of the object and set a color to represent (in the single line diagrams) the modifications introduced by it. The activation time of the variation is automatically set according to the expansion stages stored inside (the 'starting' time is the activation time of the earliest expansion stage, the 'complete' time is the activation time of the latest expansion stage). If no expansion stages are defined, the activation time is set by default to 01.01.1970. The *Contents* button can be used to list in a data browser the expansion stages stored inside the variation. A variation can be copied within the current active project or in other projects; it can only be deleted if not active.

To create a expansion stage, right-click on the target variation and select `New -> Expansion stage`. Alternatively, while the variation is selected, click on the "New Object" button in the icon bar of the Data Manager. Set the "Element" field to "Expansion stage (IntSstage)". Press OK. The dialogue of the new expansion stage pops up. There you can define the name of the new expansion stage and its activation time. The option 'Exclude from activation' can be enabled in order to put the expansion stage "out of service". If the parent variation is active, the user is asked (after pressing **OK** on the new expansion stage dialogue) if the new expansion stage should be set as the recording variation. An affirmative answer automatically adapts the study time to the activation time of the expansion stage. You can create as many expansion stages as needed for the study. The expansion stages are by default sorted according to their activation time in ascending order.

### 2.3.2.2 Activating a Variation

To activate a variation right-click on it and select `Activate` from the context sensitive menu. The variation and the belonging expansion stages will be activated based on their activation times and the current study case time. The expansion stages will be highlighted depending on the study time, indicating their activation status.

Figure 2.6 is an example showing how the expansion stages are coloured according to the specified times. The study time of "Study Case A" is set between the activation time of "Expansion stage 2" and "Expansion stage 3". Consequently, "Expansion stage 1" is coloured dark red indicating that the changes introduced into the network in that stage are effective. "Expansion stage 2" is coloured light red indicating that the changes introduced in this stage are effective, furthermore, any other changes made in the network will be recorded in this expansion stage. In other words, it is the *Recording Expansion stage*. Expansion stage 3 is not coloured meaning that for this study case it is dormant.

*Note:* More than one variation can be active for a study case. However there will always be only one recording stage.

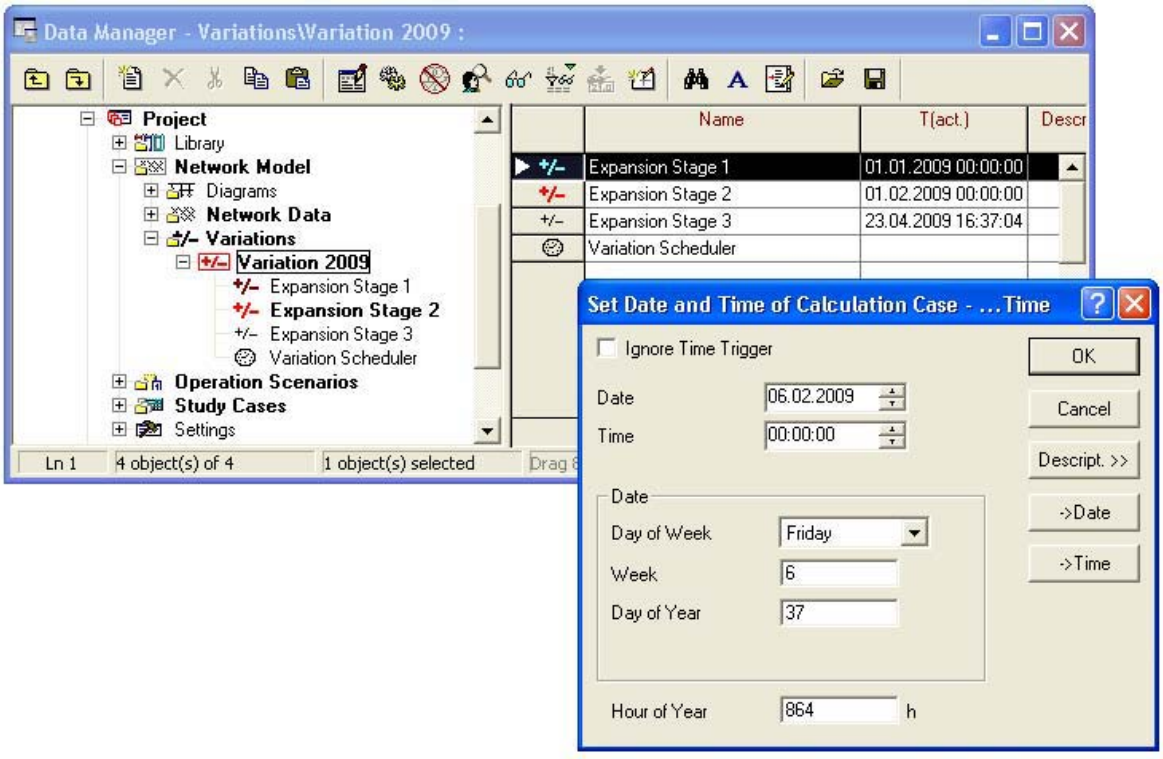


***Figure 2.5: Example showing the colouring of expansion stages according to the activation times***

### 2.3.2.3 Deleting an Expansion Stage

To delete an Expansion Stage, first deactivate the variation. Right-Click the expansion stage and select delete. Note that the elements are deleted to the "Recycle Bin". They are not completely deleted, , until you empty the Recycle Bin. In case the expansion stage was used to create data using "DPL-Script", then repeating this script might necessitate the deleting of the corresponding expansion stage elements in the Recycle Bin.

### 2.3.2.4 Displaying the Activation Times of Expansion Stages

To check the activation time of a expansion stage, go to the variation in the data manager. If you select the variation on the left window of the data manager, you will see the list of expansion stages on the right panel. The activation time for each stage will be listed there as well.

### 2.3.2.5 Editing the Activation Times of Expansion stages

To edit the activation time of an expansion stage, go to the variation in the data manager. First you have to deactivate the complete variation. If you select the variation on the left window of the data manager, you will see the list of expansion stages on the right panel.

Double-click the stage you want to edit, to open the "Edit" dialog. Use the button to change the activation time for the stage. You can also exclude the stage from activation.

### 2.3.2.6 Setting a Expansion stage as the Recording Stage

The recording expansion stage is the stage in which the latest changes by the user are saved. When a variation is activated for a study case, the activation times of the expansion stages are compared with the time of the study case, and the stage with the largest activation time but smaller than or equal to the study time is automatically selected as the recording stage. The user has the possibility to set the recording stage explicitly by right-clicking on the expansion stage and choosing `Set 'recording' Expansion stage`, in which case the study time will be changed to the activation time of the corresponding stage.

### 2.3.2.7 Displaying the Recording Expansion stage in the Status Bar

Status bar is at the very bottom of the screen below the output window. To display the recording expansion stage in the status bar, right-click on the right-most field, and choose `Display Options -> 'Recording' Expansion stage`.

### 2.3.2.8 Checking/Editing the Study Time (Date / Time of the Calculation Case)

Double-click the study case or open the "Edit" dialog by right-click. Use the button to change the activation time for the study case. Alternatively, press on the "Date/Time of Calculation Case" button, . This will open the same window where you can set the time. Lastly, at the lower right corner of the screen the time of the simulation case is displayed. By double-clicking on this field you are taken to the same window. The study time can change the recording expansion stage explicitly.

### 2.3.2.9 The Variation Scheduler

The default activation of expansion stages is carried out according to their study time, as described above. The so called 'Variation Scheduler' can be used as an alternative method to manage this activation order. The Variation Scheduler (objects of the class IntSscheduler) stores references to the existing stages on a variation and manages different activation times and out of service ('Exclude from activation') options. The Variation Scheduler is an object inside the variation that, when activated, is able to modify the activation time of expansion stages so that the order in which they take effect in the model is changed. The activation times of the stages return to their original values when the Variation Scheduler is deactivated.

The user can define a Variation Scheduler, which includes all the stages of the variation, setting different activation times and not considering certain stages. If the scheduler is activated, the activation order of the stages will be determined by the study time and the activation times set in the scheduler, regarding of course the out of service options from the Scheduler. In this case the settings from the expansion stages objects (IntSstage) are ignored.

The user can define as many as required variation scheduler in a variation, but only one can be activated at a time.

In order to create a Variation Scheduler, open a Data Manager, and display on the left-hand side the variation in which the scheduler must be inserted. Right-click on the variation and choose *New -> Variation Scheduler*. As alternative you may click on the 'New Object' button and select Variation Scheduler (IntScheduler). The dialogue of the new Scheduler will pop up. The stages from the variation will be automatically referred in the new scheduler. Press the Contents button to open a data browser listing the included stages with their activation times and out of service options.

The activation time and the 'out of service' option of the stages within a Scheduler can only be changed in non active schedulers, by pressing the Contents button and writing the desired values in the data browser. These changes of course do not affect the expansion stage objects and only are effective when the scheduler is active. Variation Schedulers are activated or deactivated via the context sensitive menu on the Data Manager.

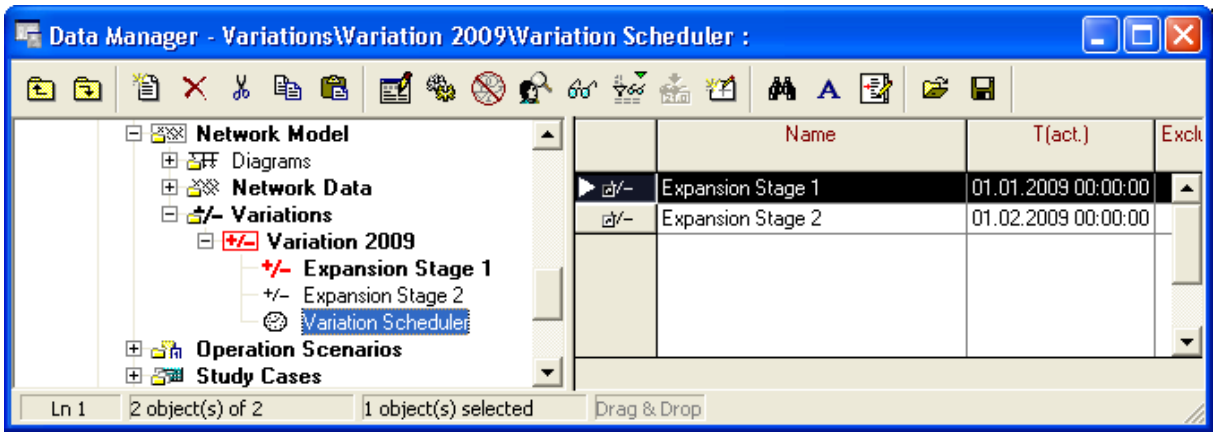


***Figure 2.6: The Variation Scheduler inside a Variation***

Figure 2.6 shows the state in which the activation times of the stages can be edited inside the scheduler. The variation must be active and the scheduler inactive. Display the contents (references to expansion stages) of the scheduler on the right-hand side of the data manager. The activation time of a stage can be edited by double-clicking on the reference to it in the right-hand window.

## 2.4 Network Diagrams

The symbol for graphical pages is inside the Data Manager. Grids, substations, branches, and controller types (common and composite types in ***PowerFactory*** terminology) each have a graphical page. In order to see the graphic on the screen, open a Data Manager and locate the graphic page object you want to show, click on the icon next to it, right-click and select `Show Graphic`. The "Show Graphic" option is also available directly from each of the above objects themselves. So for example you can select a grid in the data manager, right-click, and show the graphic. The graphic pages of grids and substations are to be found in the subfolder "Diagrams" ( ) under the "Network Model" folder.

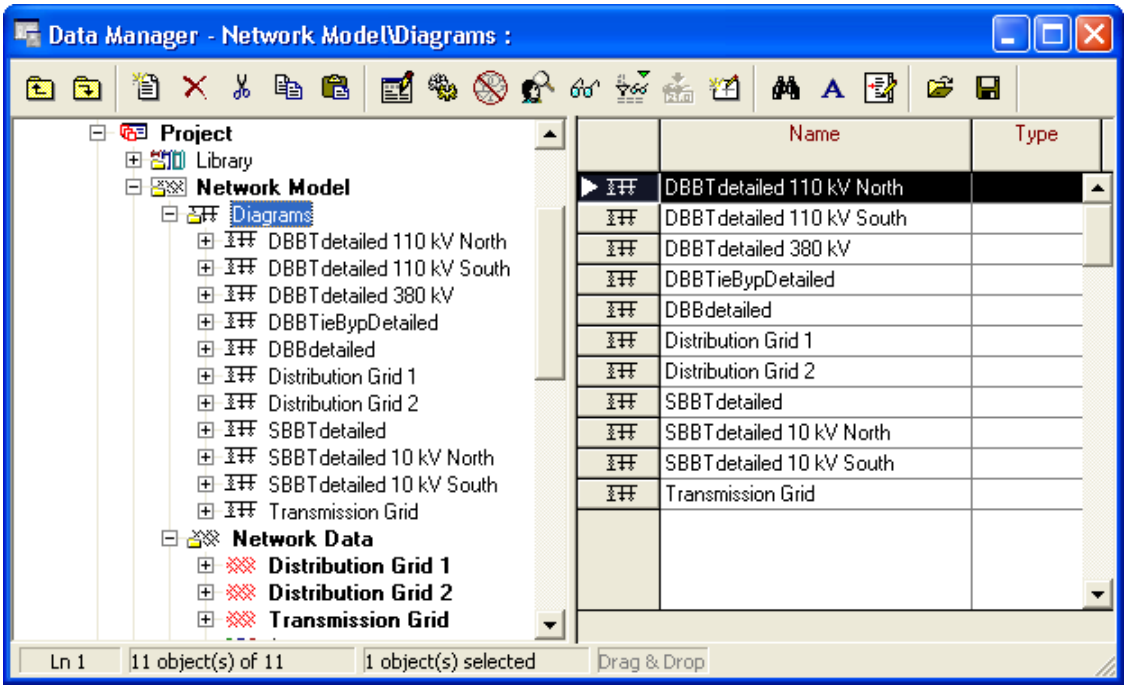


***Figure 2.7: The Diagrams folder in the Data Manager***

### 2.4.1 Creating a new substation in an Overview Diagram

Overview diagrams are single line diagrams without detailed graphical information of the substations. Substations are illustrated as "Composite Nodes", which can be coloured to show the connectivity of the connected elements

("Beach Ball"). Substations from pre-defined templates (or templates previously defined by the user) are created using the network diagrams. The substations are represented in these diagrams by means of composite node symbols.

To draw a substation from a template in an overview diagram:

- Click on the symbol of the composite node ( or ) listed among the symbols on the right-hand drawing pane.
- Then click on the "Copy from Templates" button ( ) in the icon bar of the graphic window in order to see the list of available templates for substations (from the Templates library). From this list choose the template that you want to create a substation from.
- Click on the overview diagram to place the symbol. The substation is automatically created in the active grid folder.
- Right click the substation, select "edit substation", and rename the substation accordingly.
- Close the window with the templates.
- Press **Esc** to get the cursor back.
- Resize the substation symbol in the overview diagram to the desired size.

A diagram of the newly created substation can be opened by double clicking at the composite node symbol. In the new diagram it is possible to rearrange the substation configuration and to connect the desired components to the grid.

Existing substations can be used as "models" to define templates, which may be used later to create new substations. A new substation template is created by right clicking on the substation single line diagram and selecting Add to template library from the context sensitive menu. This action will copy the substation together with all of its contents (including its diagram even if it is not stored within this substation) in the Templates folder.

**To resize a composite node:**

- Click once on the composite node you want to resize.
- When it is highlighted, place the cursor on one of the black squares at the corners and hold down the left mouse button.
- A double-arrow symbol appears and you can resize the figure by moving the mouse. For a rectangular composite node you can also resize the shape by placing the cursor on one of the sides.

**To show the connectivity inside a composite node:**

Press the button to open the colouring dialog. Select the colouring mode. Change the data, if required, for the selected mode. To show the station connectivity by the colouring select 'Station Connectivity' (Figure 2.8). It is possible to colour the beach balls according to the station connectivity in spite of selecting a different mode by enabling the option 'Always show station connectivity colour for beach balls'.

Enabling the option "Show Colour Legend" will create a legend in the active single-line diagram. You can move and resize the legend by using the graphics cursor.

If the option 'Always show station connectivity colour for beach balls' is active, it is not possible to show the selected colour option. By deactivating this option and pressing the Button OK, the selected colouring option will be showed. In this case beach balls are not coloured any more according to "station connectivity" but according to the selected colouring.

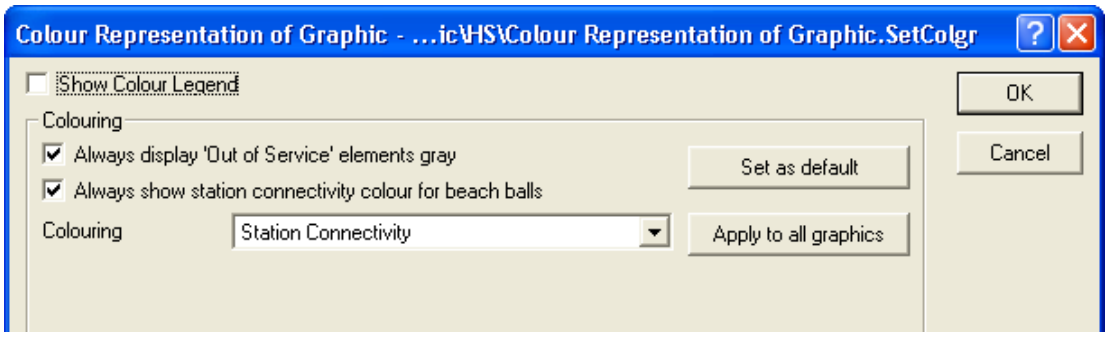


***Figure 2.8: Options for colouring graphics of single-line diagram***

The button "apply to all graphics" will change the colouring mode not only for the active diagram, but for all diagrams in the active graphics board.

## 2.4.2 Show Detailed Substation Graphic

There are two ways to open the graphic page of a substation. First is to double-click on the corresponding composite node in the overview diagram. Second is to go to the graphic object of the substation in the data manager, right-click on it and choose `Show Graphic`.

## 2.4.3 Creating a Composite Branch from Template

Go to the single-line (overview) diagram of the network. Click on the symbol of the composite branch ( ) listed among the symbols on the right-hand drawing pane.

Then from the second row of the toolbar menu on the top of the graphic window click on the "Copy from Templates" button ( ) to see the list of available templates for branches. From this list choose the template that you want to create a branch from. On the overview diagram click once on each composite node to which the branch is to be connected. You are automatically taken inside each of those composite nodes to make the

connections. In the substation graphic click once on an empty spot near the terminal where you want to connect the branch end, and then on the terminal itself. Do the same for the other end.

## 2.4.4 Drawing Existing Terminals

Click on the button "Drawing existing Net Elements" ( ) and a window with a list of all elements in the network, that are not visualized in the active diagram appears.

Right click the symbol for terminals ( ) in the drawing toolbox. The symbol of the terminal is now attached to the cursor. The list of elements in the browser window is filtered to Terminals now.

If the list is very large, press the button "Adjacent Element Mode" ( ), this activates the selecting of distance (number of elements) from elements in the active diagram. Select the Distance of 1 in order to reduce the number of terminals shown.

The marked or selected element can now be visualised or drawn by clicking somewhere in the active diagram. This element is drawn and disappears from the list.

Note that the number of elements in the list can increase or decreases depending on how many elements are a distant away from the element lastly drawn. Scroll down the list, in case only certain elements have to be visualised.

Close the window and press 'ESC' to return the Cursor to normal. The drawn terminals can be moved, rotated or manipulated in various ways.

## 2.4.5 Drawing Existing Lines, Switch Gears and Transformers

Similar to the terminals ( ), elements like lines and transformers connecting the terminals in the substation can be drawn.

Press the button "Drawing existing Net Elements" ( ). Afterwards select the symbol for lines from the drawing toolbox, for transformers select the symbol , and so on.

Similar to terminals a list of all the lines (or transformers, or elements which you have chosen) in the network, that are not in the active diagram are listed. Reduced the list by pressing the button "Elements which can be completely connected" ( ) at the top of the window with the list. A list of lines with both terminals in the active diagram is pre-selected. If the list is empty, then there are no lines connecting any two unconnected terminals in the active diagram.

For each selected line (or transformers…) a pair of terminals, to which the line is connected is marked in the diagram. Click on the first terminal and then on the second. The selected line is drawn und is removed from the list of lines.

Continue drawing all lines (or transformers…), until the list of lines is empty or all the lines to be drawn have been drawn.

### 2.4.6 The Active Grid Folder (Target Folder)

Inside the status bar of ***PowerFactory***, the active grid folder is displayed on the leftmost field. Any changes you make in the network diagram refering the data of the grid are stored inside this grid folder. To change the active grid folder (the target folder), double-click this field, a window opens in which you can select the new active grid folder.

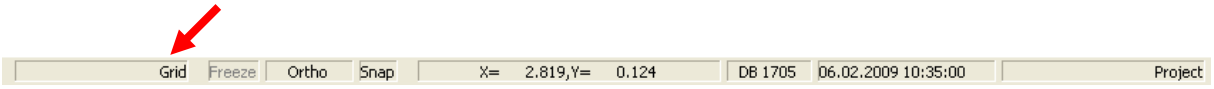


***Figure 2.9: The Status Bar***

## 2.5 The Operational Library

Network components use references to type objects in order to set parameters related to the equipment itself and avoid data redundancy. For example two generators defined in a network model (lets call them G1 and G2) may refer to the same generator type (lets call it G 190M-18kV) to set their manufacturer equipment related data, i.e. nominal voltage, nominal power, impedances, etc. G1 and G2 will have the same equipment data but may be operated at different points or may be connected to the ground on a different way. That is, they may have the same type data, but different operational and element data.

As mentioned, certain parameters of the network components do not depend on the equipment itself but on the operational point. These parameters are grouped under the operational data set of the element. In the previous example of the synchronous generators, the active power dispatch or the reactive power limits are part of this operational data.

In order to analyze a network under different operational points, operational data may change frequently during a study. Regarding that different network components may have identical operational parameters (for example 2 generators with the same Mvar limits or various circuit breakers with the same ratings for short circuit currents); references to objects storing operational data would facilitate the definition of different network operational points. Similar to types, the use of objects containing operational data avoids redundancy.

The Operational Library is the folder of the Data Model, where objects containing operational data are stored. The description of these objects and their hierarchical organization within the operational library is the subject of the following subsections. Figure 2.2 shows how the operational library looks for its higher hierarchy level.

## 2.5.1 Running Arrangements

Running Arrangements (RA, IntRunarrange ) are operational data objects that store statuses of the switches (open or close) of one substation. A running arrangement uses a reference to the substation object (ElmSubstat) whose switches statuses are stored. An application period (start and end time) is used to discriminate the use of a running arrangement, according to the study time. Running arrangements are stored in the 'Running Arrangements' folder of the Operational Library.

Different configurations of the same substation can be defined by storing the corresponding switches statuses in running arrangements. During the study, the user can apply any of the stored statuses simply by selecting the corresponding running arrangement. If a running arrangement is selected for a substation, the status of the switches can not be modified (become read only). If there is no setting for a switch in a running arrangement (RA is incomplete), such a switch will remain unchanged but its status is also set to read-only. If the current running arrangement is deselected, the switches recover the status that they had before selecting it (and of course become modifiable).

Running arrangements are defined and selected in the substation object dialogue.

### 2.5.1.1 Creating a Running Arrangement

To save the current status of the switches in a substation, a *running arrangement* object must be created. Click on an empty spot in the graphic of the substation, and from the context sensitive menu choose `Edit substation`. Press the button "Save as" (Figure 2.10). This action stores the switch settings of the substation as a new RA. This button is only available if there is currently no RA selection active. Further, a button "Overwrite" is available to store current switch statuses into an existing Running Arrangement.

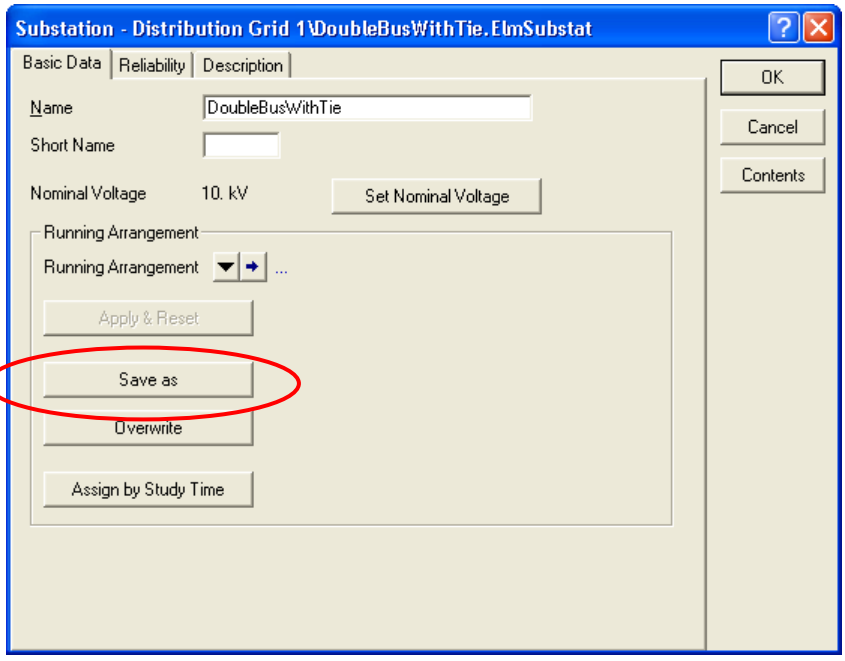


***Figure 2.10: Edit dialogue of a substation***

### 2.5.1.2 Selecting a Running Arrangement

A running arrangement can be selected in the property sheet of a substation (Figure 2.11). By pressing the "Select" button, , a list of valid running arrangements for current substation is displayed. Changing the selection is immediately reflected in the graphic (preview).

While a running arrangement is selected, the switch statuses of a substation are determined by this running arrangement and cannot be changed by the user (read-only).

If there is no setting for a switch in a running arrangement (RA is incomplete), such a switch will remain unchanged but its status is also set to read-only.

Furthermore, there is a button "Select by Study Time" (also available via the data manager's context menu) to select a valid running arrangement automatically according to study time. If there are multiple running arrangements valid for current study time or if there is no valid one, a warning is printed to the ***PowerFactory***'s output window (nothing is selected in this case).

### 2.5.1.3 Applying and Resetting a Running Arrangement

The button "Apply & Reset" in the property sheet of a substation allows copying settings stored in the selected running arrangement directly to the switches. It is available only, if a Running Arrangement is selected. The running arrangement will be deselected afterwards.

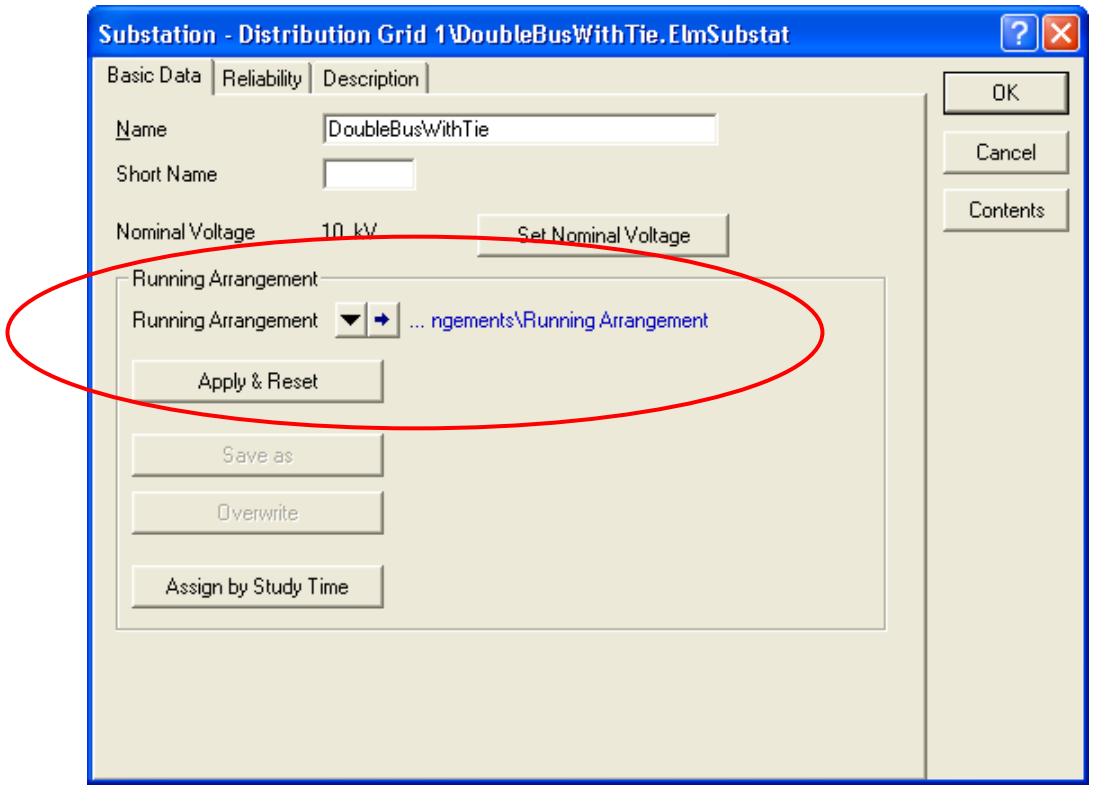


***Figure 2.11: Apply & Reset a Running Arrangement***

### 2.5.1.4 Assigning a Running Arrangement

By the button "Assign" in the property sheet of a running arrangement, it is possible to set this running arrangement as the one currently selected for the corresponding substation. This action is also available in the context menu of the data manager (click on a Running Arrangement with the right mouse button inside the data manager). Assignment is executed immediately and cannot be undone by pressing the cancel button of the dialog sheet.

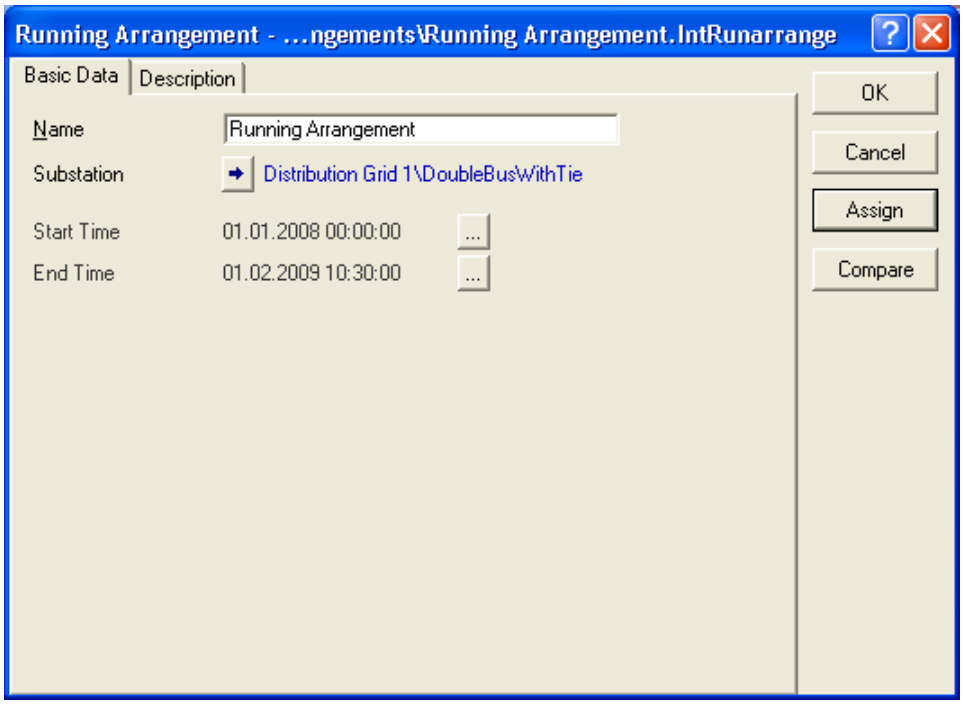


***Figure 2.12: Dialogue of a Running Arrangement***

## 2.5.2 MVAr Limits Curves / Capability Curves

The **Capability Curve objects (IntQlim)** allows the consideration of distinct minimum / maximum values of the reactive power, at different levels of active power injection. Capability curves are stored inside the '**Mvar Limits Curves**' folder in the Operational Library. Synchronous generators (ElmSym) and static generators (ElmGenstat) defined on the network model can use a pointer to a IntQlim object from the load flow page of their edit dialogue. When a capability curve is used, the dispatch of the generator always stays within its minimum and maximum range. For more details about defining and using Capability Curves please refer to chapter 4.2 of this document.

To create a new generator capability curve (object of the class IntQlim), open the folder Mvar Limit Curves from the Operational library, click on the 'New Object' icon and select Capability Curve (IntQlim). The edit dialogue of the new capability curve pops up. Add the required number of rows to the table (right click on the left side of the table and select Append n Rows or Append Rows from the context sensitive menu), define the generation limits and press Ok.

The values of a capability curve can be changed at any time by double clicking on it to open the corresponding edit dialogue. Similar to circuit breaker ratings, capability curves can become time dependant by means of variations and expansion stages stored inside the Mvar Limit Curves folder.

Capability curves are assigned using the reference from the 'Load Flow' tab of the synchronous generators. They are included in the operation scenario subsets; therefore if a capability curve is selected/reset from a generator when an operation scenario is active, the change will be stored in the operation scenario. Once the operation scenario is deactivated the assignment/reset of the curve is reverted.

# 2.6 Operation Scenarios

The operational data of the network components defines the operational point of a system. Storing recurrent operation points of and being able to activate or deactivate them when required, accelerates the analyses of the network under different operative conditions, e.g. different dispatch programs, low or high load periods, etc. ***PowerFactory*** can store complete operation points under objects called Operation Scenarios (IntScenario, ).

Operation Scenarios are formed by data subsets, which group the operational data of the active network components according to their type. Examples of Operation Scenario's subsets are the Demand Data, storing the active and reactive power of all the loads or the RA Selections, storing references to the running arrangements selected in the network substations.

Operation Scenarios are stored inside the 'Operation Scenarios' folder ( ) in the Project directory. The user can define as many operation scenarios as required; each operation scenario should represent a different operational point.

A new operation scenario is defined by saving the current operational data of the active network components. Once they have been created, operation scenarios can be activated in order to load the corresponding operational data. If an operation scenario is active and certain operational data is changed, these changes are stored in the corresponding operation scenario subsets (if the user decides to store the changes). If the current operation scenario is deactivated, the active network components reassume the operational data that they had before activating the operation scenario (that is the 'default' operational data). Clearly, changes on the 'default' operational data do not affect operation scenarios.

When working with active operation scenarios and active expansion stages, modifications on the operational data are stored in the operation scenario subsets, the expansion stage keeps the default operational data. If no operation scenarios are active and new components are added by the current expansion stage, the operational data of the new components will add to the corresponding operation scenario subsets, when activated.

## 2.6.1 Creating a new Operation Scenario

In order to create a new (empty) Operation Scenario:

- In the Data Manager right click on the operation scenarios folder of the active project.
- Select New --> Operation Scenario from the context sensitive menu as shown in Figure 2.13.
- The dialogue of the new operation scenario pops up, write the name and press Ok.

Alternatively, an Operation Scenario can be created by the saving operational data of the current active network components. This is done by the item `Save Scenario as…` from ***PowerFactory***'s main menu "File". In this case the new operation scenario is automatically activated.

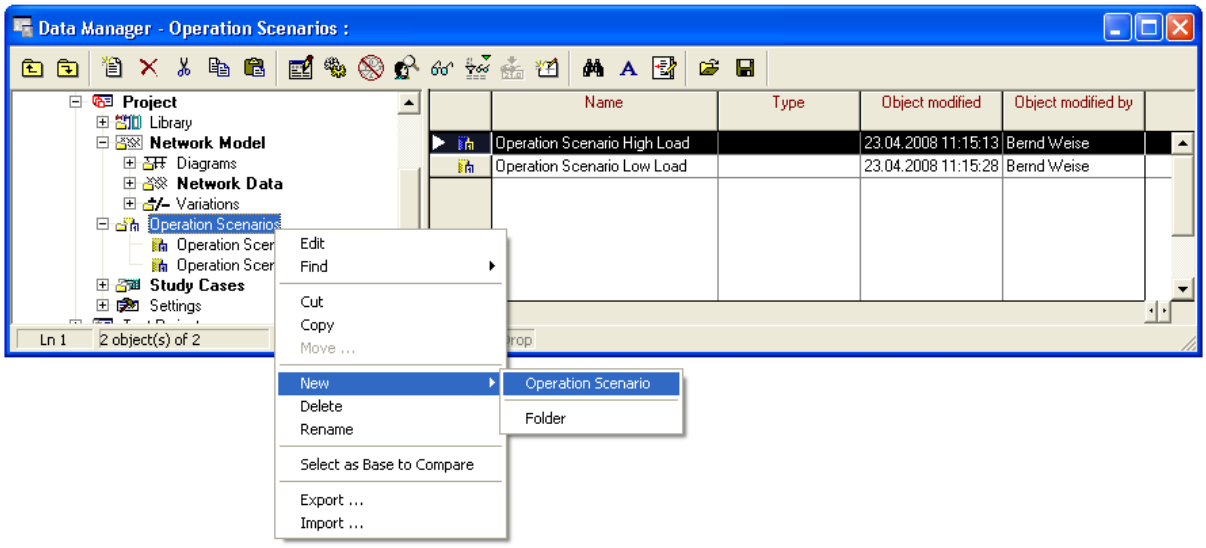


***Figure 2.13: Creating a new Operation Scenario object using the data manager***

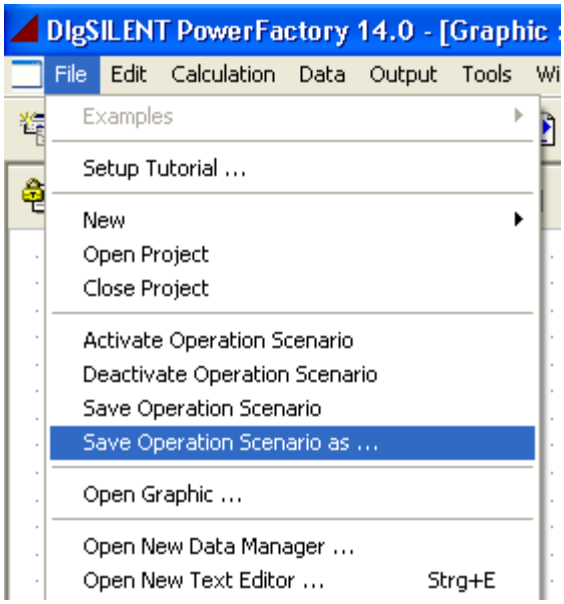


***Figure 2.14: Using the main menu to save as a new Operation Scenario***

## 2.6.2 Activating an Operation Scenario

An operation scenario is activated by right click on it (in the Data Manager) and selecting Activate from the context sensitive menu. Alternatively the option Activate Operation Scenario from the main menu can be used. If another operation scenario is active, the active operation scenario is first deactivated; the user is asked if he/she wants to save the changes (if any) and the new operation scenario is activated. When an operation scenario is activated a reference is created in the current study case.

On activation, a completeness check is done:

- Check if operational data is available for all components.
- Check if the all the defined operational data from the new operation scenario subsets can be applied to the Network Model.

The results of the check are reported as messages in the Output window. When an operation scenario is incomplete at activation, the 'default' operational data is set for the 'incomplete' elements, modifying the operation scenario.

If an operation scenario is active, all operational data attributes in property sheets or in data manager are highlighted in a blue color. This indicates that changes of these values will not modify the base component (or variation) but are recorded by the active operation scenario.

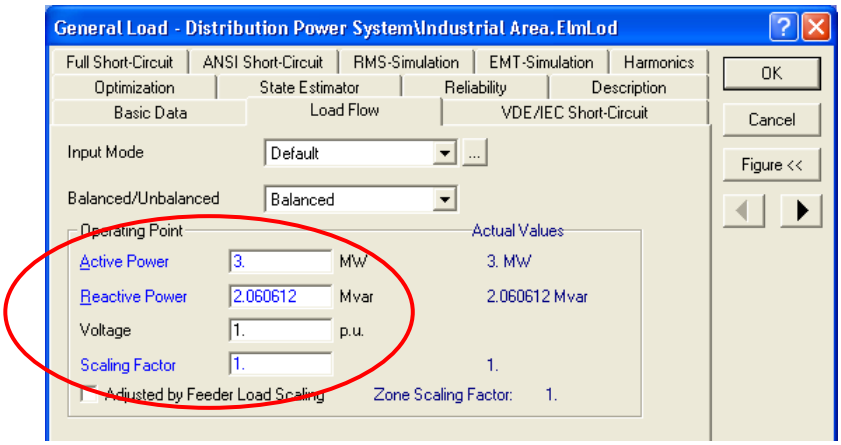


***Figure 2.15: Blue highlighted operational data in an element dialogue***

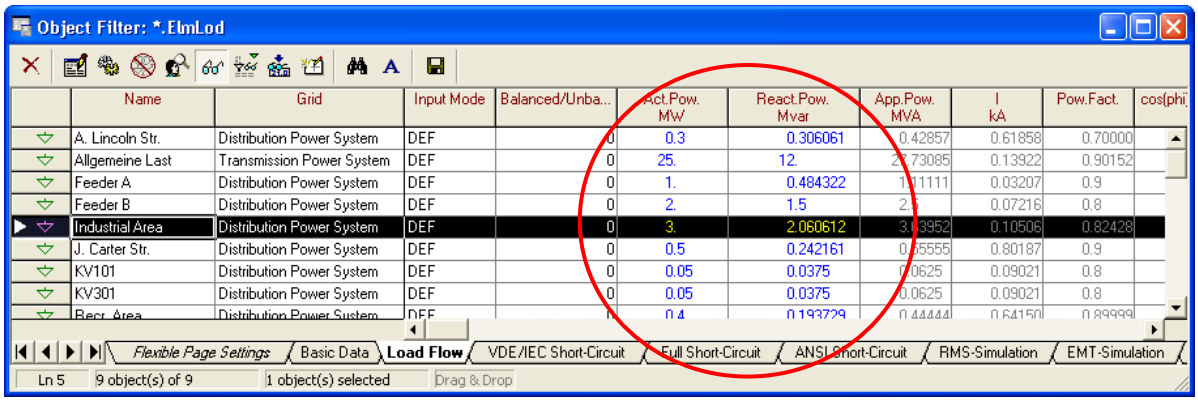


***Figure 2.16: Blue highlighted operational data in a browser window***

## 2.6.3 Saving an Operation Scenario

A new Operation Scenario may be created by selecting from the main menu 'File -> Save Operation Scenario as…'.

If any operational data (of a network component) is changed while an Operation Scenario is active that scenario is considered to be modified. The modifications are not saved, as indicated by an asterisk (*) in the icon for the Operation Scenario. Further, an incomplete Operation Scenario is also considered modified (because data will be completed on saving).

***Figure 2.17: An asterisk indicates unsaved changes in Operation Scenarios***

A modified Operation Scenario can be saved to database by

- the menu entry `Save Operation Scenario` in ***PowerFactory***'s main menu "File" (see Figure 2.14),
- the button "Save" in the dialogue window of the Operation Scenario (see Figure 2.21),
- The button "Save Operation Scenario" in the main icon bar (see Figure 2.18).
- the context menu (right mouse button) entry "`Save`" of the Operation Scenario (Figure 2.19),

Additionally, an auto-save for Operation Scenario data is available, which will always save a modified scenario automatically. This option can be enabled on the Data Manager tab in the ***PowerFactory*** user settings (main menu `Tools -> User Settings…`), see Figure 2.20. If the "Save Interval" is set to "0 minutes", each modification will immediately be saved to the database.

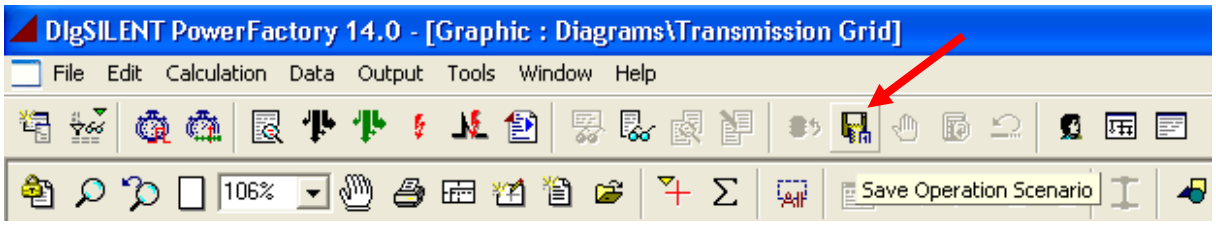
DIgSILENT PowerFactory 14.0 - [Graphic : Diagrams\Transmission Grid]
File Edit Calculation Data Output Tools Window Help
106%
Save Operation Scenario

***Figure 2.18: The button "Save Operation Scenario" in the main icon bar***

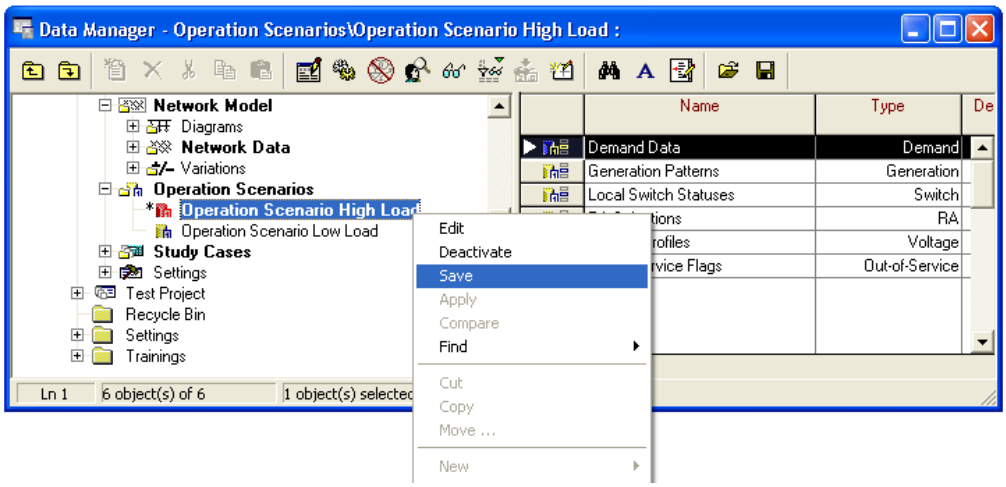


***Figure 2.19: Saving an Operation Scenario using the context menu***

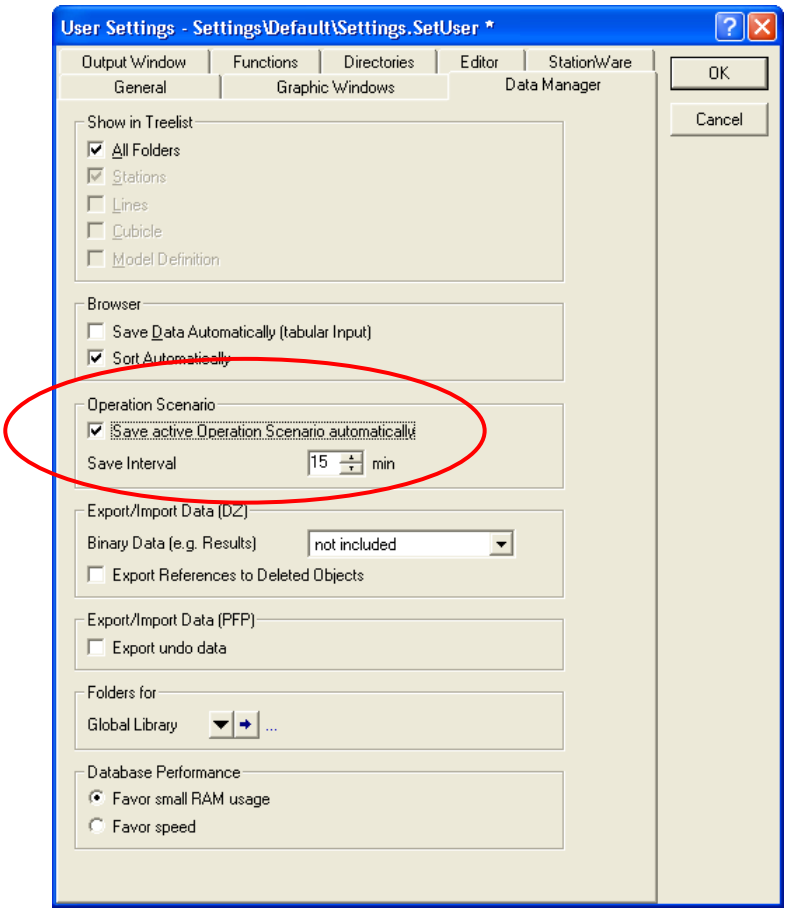


***Figure 2.20: The auto-save option for Operation Scenarios in the user settings dialogue***

## 2.6.4 Deactivating an Operation Scenario

An Operation Scenario can be deactivated via the main menu `File -> Deactivate Operation Scenario` or by the context menu of the active Operation Scenario. On deactivation, previous operational data are restored. If the Operation Scenario was modified, a user confirmation is requested whether to save the changes or to discard them.

## 2.6.5 Performing Actions on Operation Scenarios

On the property sheet of a scenario, the following actions are available:

- **Save:** Saves modified scenario to database (only active if scenario was modified)
- **Save as:** Saves current operational data of network components as a new scenario. The new scenario will automatically be activated afterwards.
- **Reporting:** Checks if operational data stored in scenario are complete (available for all currently active components) and refer to valid components. Inconsistencies are reported to the ***PowerFactory*** output window.
- **Apply:** Copies all operational data stored in the scenario to the network components without activating the scenario. If another scenario or a variation is active, it will record these values. Else, the base model is changed.
- **Compare:** Compares two scenarios and prints a comparison report to the output window. (Only inactive scenarios can be compared.)
- **Reporting RA:** Non-default running arrangement selections will be reported (only enabled if scenario is active)

Most of these actions are also available in context menu of an Operation Scenario.

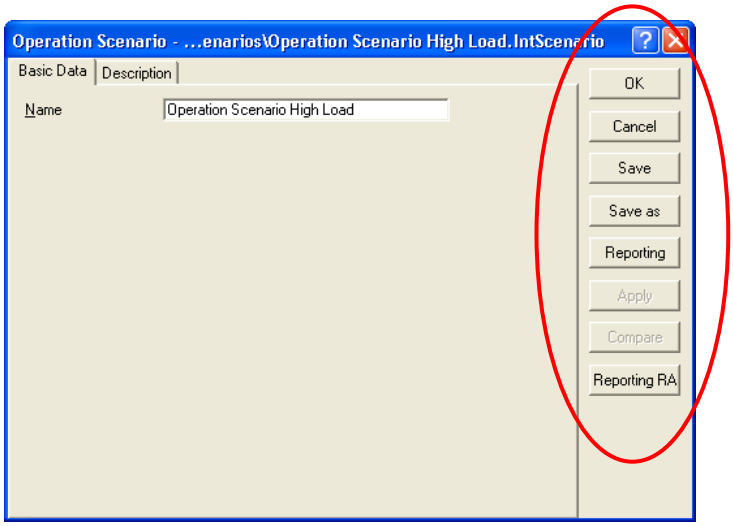


***Figure 2.21: Dialogue of the Operation Scenario object showing the "Basic Data" page***

## 2.6.6 Copying a Subset of an Operation Scenario to Another Operation Scenario

The operational data are recorded in several subsets inside an Operation Scenario. The data of each subset can be transferred from one Operation Scenario to another. Suppose the "Running Arrangement Selections" from "Operation Scenario Low Load" must be applied to "Operation Scenario High Load". First Activate the target Operation Scenario (here "Operation Scenario High Load"). Then display the subsets of the source Operation Scenario (here "Operation Scenario Low Load") on the right-hand side of a data manager window. Right-click on the subset to be applied (here "RA Selections"), and choose `Apply (see` Figure 2.22`)`.

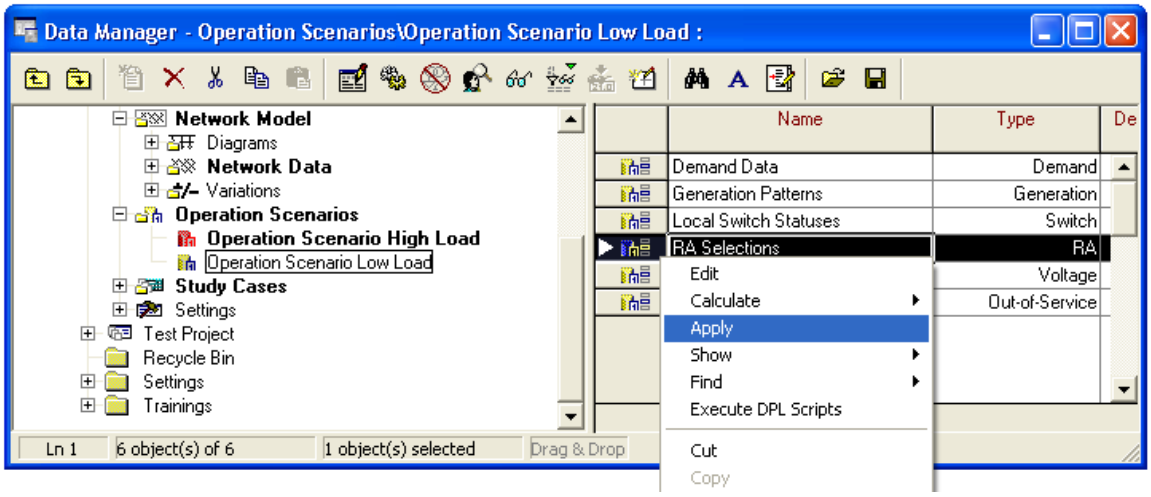


***Figure 2.22: Applying subsets from one Operation Scenario to another***

## 2.6.7 Comparing two Operation Scenarios

If one of the Operation Scenarios to be compared is activated, deactivate it. Right click one of the Operation Scenarios and select "compare" from the context menu. A window is opened, from which we can select the other Operation Scenario to which we want to compare (see Figure 2.23). ***PowerFactory*** prints the differences between both Operation Scenarios in the output window.

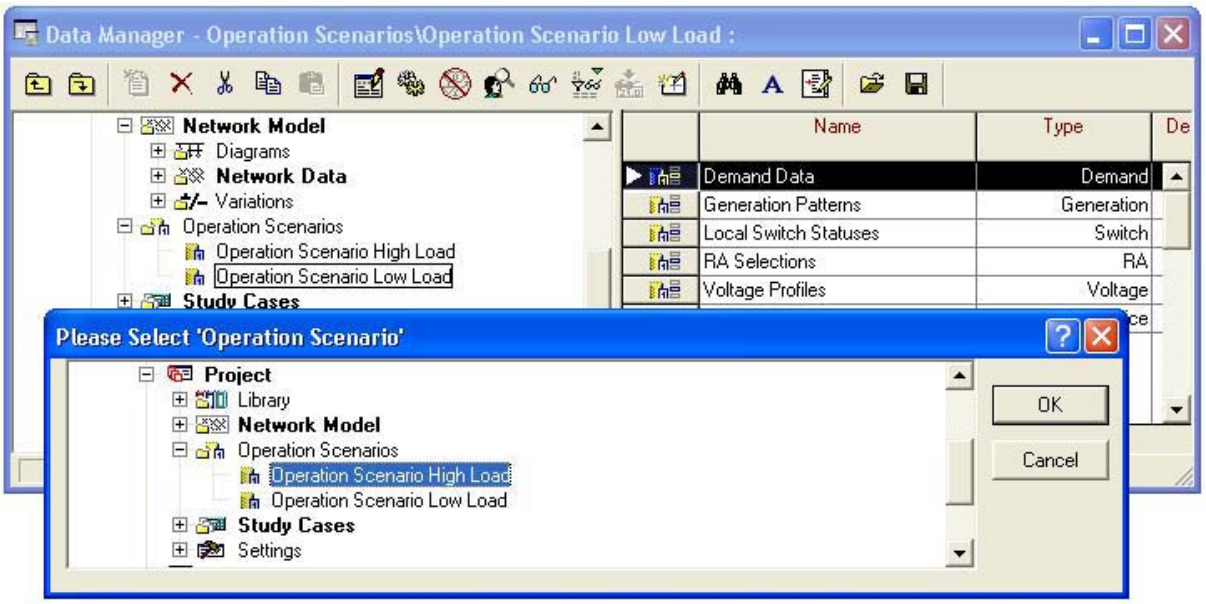


***Figure 2.23: Selecting Operation Scenarios to compare them***

# 3 Data Organisation

For version 14 a lot of enhancements have been done to improve the data organisation. As highlights the "Versions", the new import/export file formats *.pfd are described here.

## 3.1 Versions

To fix and safe a certain state of the project, there is a new possibility in ***PowerFactory*** to create "Versions" of the project. A "Version" is a snapshot of a Project taken at a certain point of time. By means of versions, the historic development of a Project can be controlled and reverted if required. From the database point of view a version is a read-only copy of the original project (at the moment of creation), which is stored inside a version object (IntVersion,). Version objects are stored inside the original project in a folder called versions.

### 3.1.1 Creating a version

To create a version:

- Activate the project
- Right-click the project and select 'New -> Version'
- In the upcoming dialog, you can select, if you want to create
    - a regular version, where all users will be notified and can update their projects
    - a test version, which is a internal version and the user will get no notification

The user is able to create a derived project from a regular as well from a test version

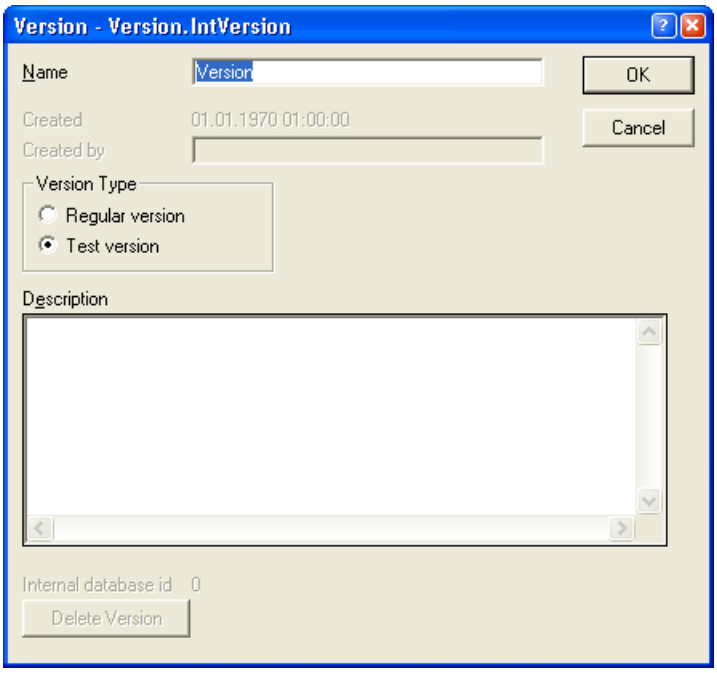


***Figure 3.1: Creating a new project version***

## 3.1.2 Rollback Function

The state of a project at a certain version can be recovered by means a function called 'Rollback'. If a 'Rollback' is performed, the project returns to the state it has at the creation of a selected version (let's called it 'v'). With the Rollback, all the changes implemented after 'v' (at v's point of time) are deleted. All versions newer than 'v' are also removed.

To perform a 'Rollback':

- Deactivate the target project.
- Right click on the 'v' version and select Rollback to this version from the context sensitive menu.
- "Press Ok on the confirmation message.

Notice that a 'Rollback' is not allowed (not enabled in the context sensitive menu) if a version to be deleted is the base of a derived project. **A Rollback can not be undone**!

## 3.1.3 Checking dependencies of a version

To check dependencies of a Version:

- Activate the project.

- Go to the version folder inside your project.
- Right-click the version, you want to edit/delete.
- Select the option 'Action -> Output derived projects'
- You will now get a list of derived projects in the output window of ***PowerFactory***.

### 3.1.4 Delete a version

To delete a Version:

- Activate the project.
- Go to the version folder inside your project.
- Right-click the version, you want to edit/delete.
- Select the option 'Action -> Delete Versions'

or

- Open the edit dialog of the version.
- Use the button 'Delete Version' to delete the version.

## 3.2 Derived Projects

At certain stages of a system study several users may work on the same project. To avoid the huge amount of data that implies a project copy for each user, **DIgSILENT** has developed a 'virtual copy' approach called Derived Projects. From the users point of view a derived project behaves like a normal copy of a project version; internally only the differences between the original project version ('Base Project') and the virtual copy ('Derived Project') are stored. Because the derived project is based on a version, changes on the base project do not affect it. Like "normal" projects, derived projects can be controlled in time by means of versions, however this 'derived' versions can not be used to create further derived projects.

**Note:** A Derived Project is a local "virtual" copy of a Version of a (base) project (master project):
- It behaves like a "real copy" from the user's point of view.
- Internally only the data differences between the "Base Project" and the "Derived Project" are stored in the database.
- This approach avoids the data overhead.

In a multi user database the data administrator may publish a "base" project in a public area of the data base. Each user can create an own Derived Project and work with it like working with the original base project. Changes made by the user are stored in the Derived Project, so that the base project remains the same for all users.

The purpose of a Derived Project is, that all users use the same power system model. The Derived Project remains connected to the base project always.

The concept of the derived projects is illustrated by means of figureFigure 3.2; here the Version 2 of the Base Project was used to create the Derived Project. After Derived Project was created, two versions of it were generated.

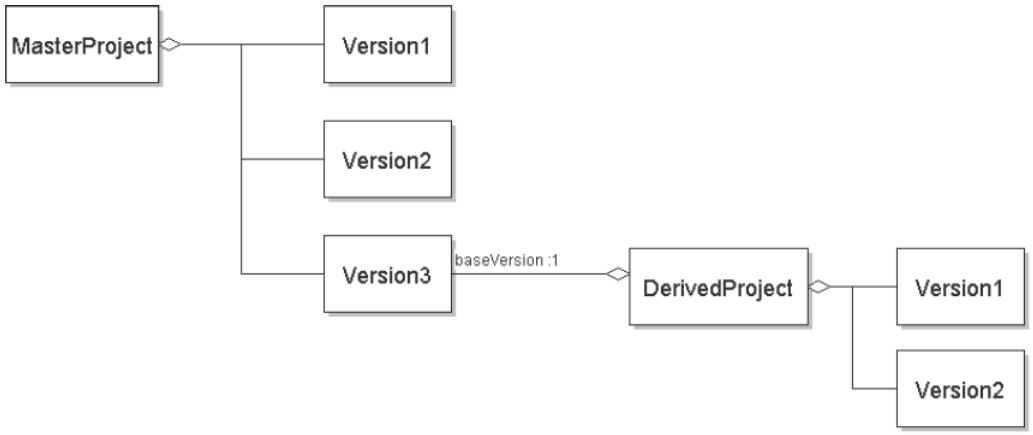


***Figure 3.2: Principle of Derived Projects***

A new derived project is created using the Data Manager by:

- Right Clicking the folder in your user account on right pane of the Data Manager where the Derived Project is to be created.
- Selecting *New --> Derived Project* from the context sensitive menu.
- Selecting from the data browser that pops up the source version of the base project. Probably this will be the last available version of a project in a public area, which your data administrator has created.
- Press **OK**.

**Note:** The base or master project has to have at least one version before other projects can be derived from it.
You cannot derive a project from a derived project.
You can find if a project is derived or not by opening the Edit dialogue box of the project.
To create a Virtual Project from a Base Project stored in other user's account you need at least read access (see Sharing Projects).

Once the derived project is created, you can start to use it like a normal project. In a step forward you would like to update the derived project from new versions of the base, or even update the base with your derived project. All of these features are possible, as explained in chapter 3.3 (Comparing and Merging Projects), by means of the Merge Tool.

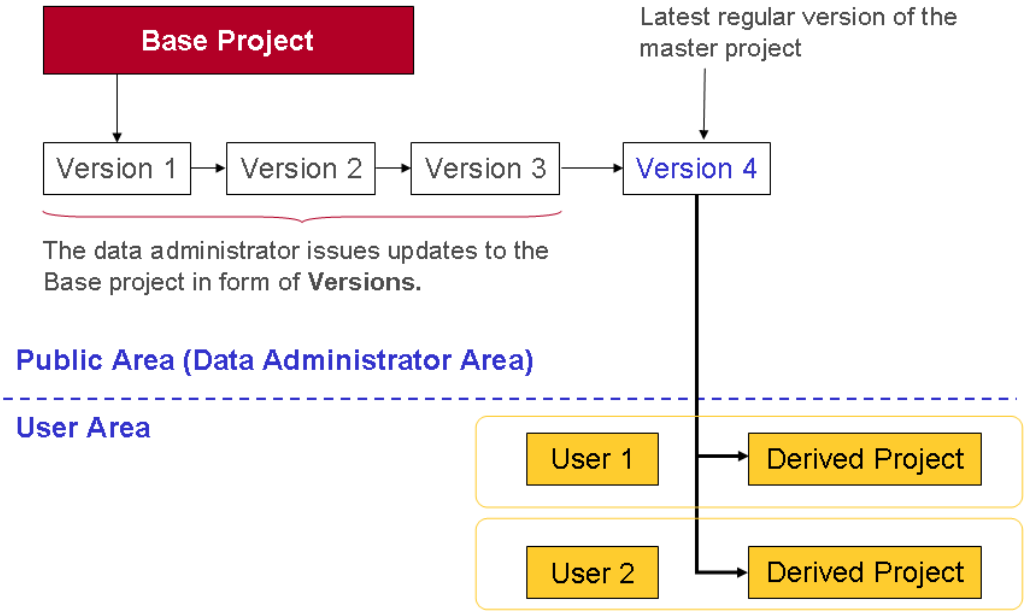


***Figure 3.3: Derived Projects in a multi user data base***

In the Data Manager a virtual project looks like a normal project. The 'Derived Project' tab of its dialogue has a reference to the base project and the used version.

Users are notified of changes in base project, if there is a new version of the base project (newer than the 'used' version) marked with 'Notify users of derived projects' and the option 'Disable notification at activation' disabled. The possibility to update the derived project is presented to the user at activation (of the derived project). The newest version that can be used to update a derived project is referred (if available) in the 'Most recent version' field of the dialogue. The users can compare this new version with their own derived project and decide which changes should be included in the derived project. For comparing and for accepting or refusing the single changes the Merge Tool is used. For information about the Merge Tool please refer to chapter 3.3 (Comparing and Merging Projects).

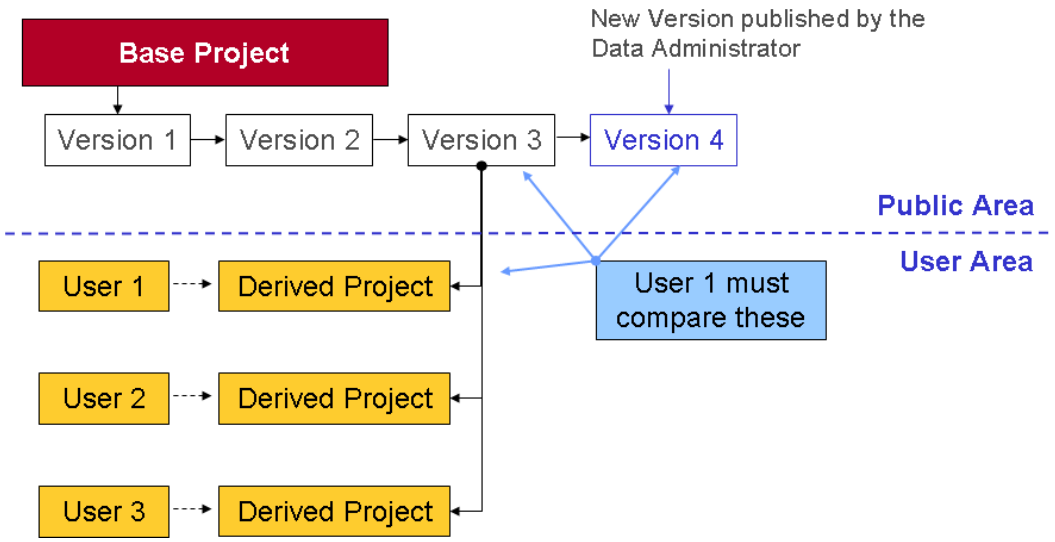


***Figure 3.4: New Version of the base project in a multi user data base***

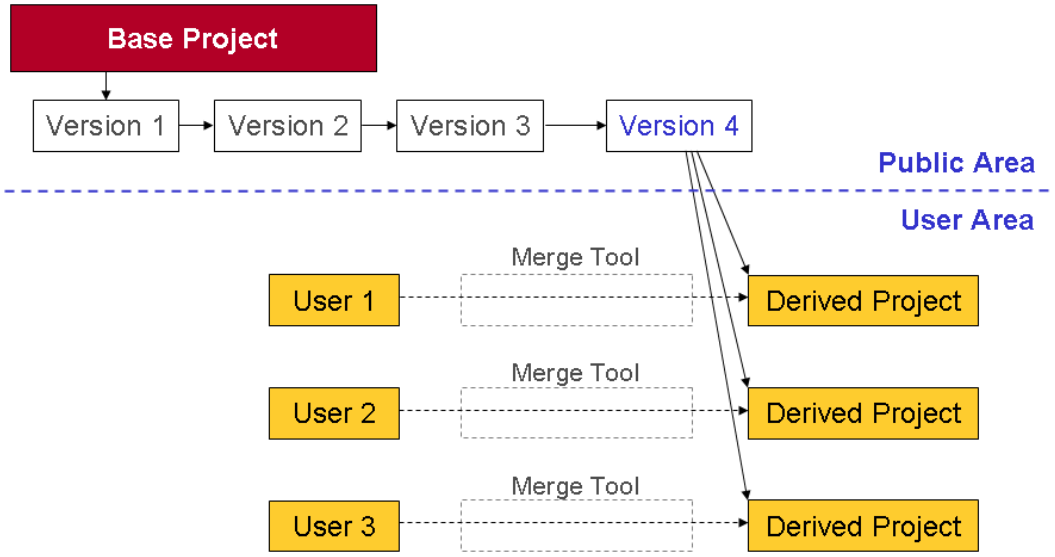


***Figure 3.5: Merging the new version of the base project into the Derived Projects***

# 3.3 Merging Projects / Versions

If you have different versions of a project or different copies of the project, you can use the merge tool to indicate the differences and bring the different versions together.

## 3.3.1 Starting the Merge Tool

To start the merge tool, you have to first deactivate all projects, which will be part of the compare/merge process. There are different ways of starting the merge tool.

For ***tracking changes*** between two projects use:

- Right-click a project at choose `Select as Base to Compare`.
- Right-click a second project and select the option `Compare to "Other Project"`.

For ***merging a derived project*** into the baseline use:

- Right-click the derived project.
- Choose the option `Action -> Merge` from the context sensitive menu.

A third option and most flexible method is to:

- open the merge tool in the same way as in the first option
- setting up the merge tool in its dialog according to the following instruction.

## 3.3.2 Setting up the Merge Tool

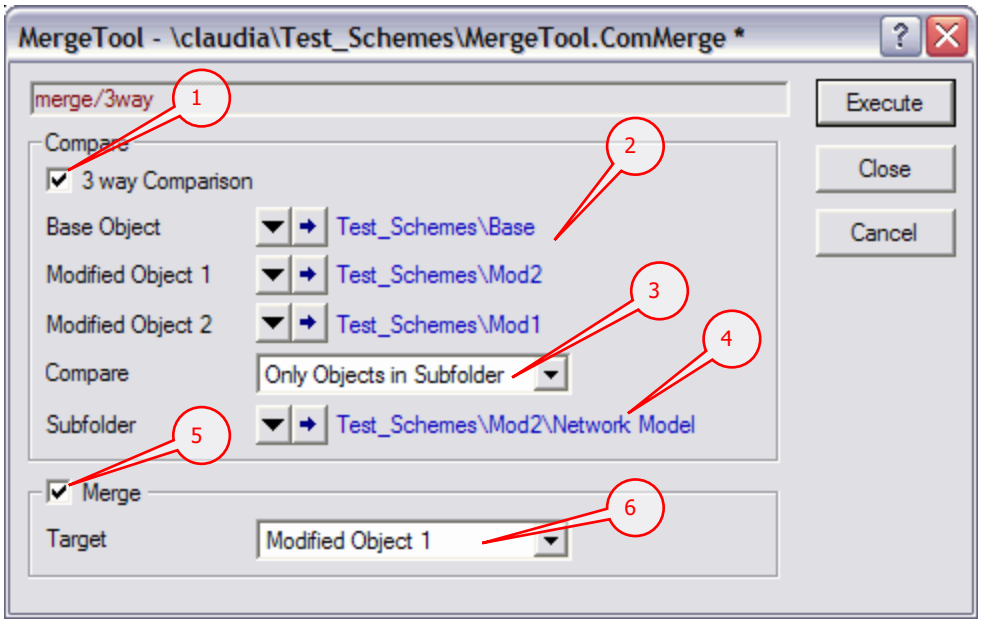


***Figure 3.6: Starting the MergeTool***

1 Off → One object has to be chosen as base object, and one as modified object
On → One base and two modified objects have to be chosen

2 Objects to compare
→ Base is unmodified
→ All kinds of objects (not only projects) can be chosen

3 All contained objects → All objects contained by the chosen objects are compared, the chosen objects themselves are ignored
Only chosen objects → Only the chosen objects are compared, contained objects are ignored
Only Objects in Subfolder → Start comparison in selected subfolder

4 Folder to start comparison in
→ Can be chosen in one of the objects above but has to exist with the same path in all objects chosen above
→ Only visible if "Only Objects in Subfolder" was chosen in **3**

5 On → After the comparison (when all objects were assigned in the DifBrowser) the assigned objects can be merged into the target
Off → Only comparison

6 Object into that the assigned objects are merged
→ In 2 way comparison always Base
→ In 3 way comparison Mod1 or Mod2

## 3.3.3 Introducing the Merge Tool Main Toolbar

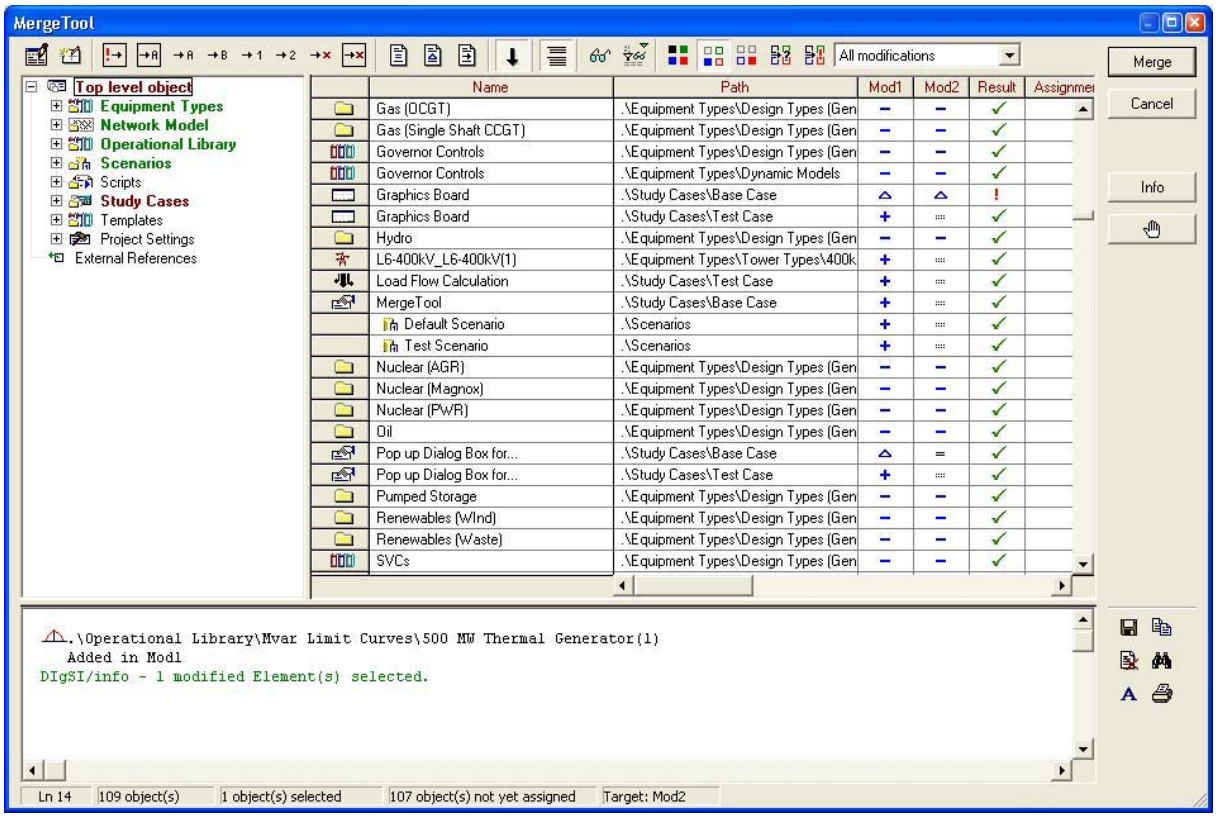


***Figure 3.7: MergeTool – Main window***

Show Object
→ Shows one of the parameter dialogs for selected object
→ The object for which the dialog is shown is chosen in the source selection dialog

Refreshes the table
→ The comparison is not refreshed

Buttons for assignment
→ Only active if merge option was chosen in the object selection dialog
Handle conflicts → Shows the source selection dialog and assigns all compared objects with conflicts (!) or undefined status (empty), but it does not overwrite older assignments

Assigns all compared objects automatically according to the following table

| Mod1 | Mod2 | Assign from |
|---|---|---|
| = | = | Target |
| = | △ | Mod2 |
| △ | = | Mod1 |
| = | + | Mod2 |
| + | = | Mod1 |
| = | - | Mod2 |
| - | = | Mod1 |
| △ | △ | Modified both but equal: Target<br>Else: None |
| △ | - | None |
| - | △ | None |
| + | + | Modified both but equal: Target<br>Else: None |
| - | - | Target |

Assigns all selected objects automatically (see above)

Assigns all selected objects from "Base"

Assigns all selected objects from "Mod1"

Assigns all selected objects from "Mod2"

Deletes assignments for all selected objects

Deletes assignments for all compared objects

Print comparison report
→ Prints all compared objects with its modification flags and dependencies to the output window

Print modifications
→ Prints the modifications of all selected and modified objects to the output window
→ Unmodified objects are not reported
→ If parameters were changed the values of the modified parameters are also reported

Check Assignments
→ Checks if all objects are assigned and if the assignments lead to a conflict
→ Prints a report to the output window
→ If conflicts were detected, the conflict is shown in the "Conflict" column of the table for the affected object

Shows only differences in chosen folder

Shows dependencies by grouping objects (objects can be shown more than once)

Shows all objects

Shows only modified objects

Shows only modified objects

Shows only objects with conflicts

Shows only objects not yet assigned

Here you can select if you want to show:

- only modifies objects
- added objects
- deleted objects or
- All modifications

Shows detailed information of the current comparison/merge, i.e. the base, mod1 and mod2 object. Target object (for merge only) and the number of objects and differences.

Use the stop button to stop the merge tool to stop a command e.g. print a long report
It is NOT possible to stop the merging process when started!

## 3.3.4 Introducing the Merge Tool Browser

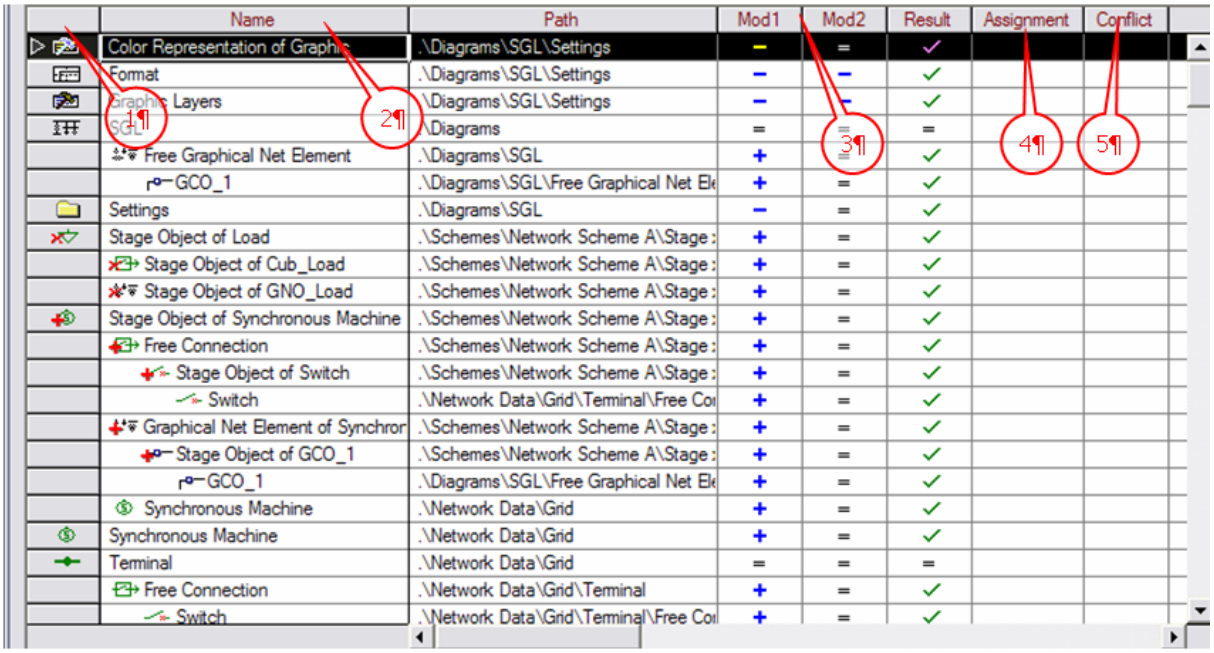


***Figure 3.8: MergeTool – Layout***

1 → The balloon help shows the compared objects

2 → Dependent objects are indented
→ After the action "Compare with" recompared objects are highlighted

3 → The balloon help shows a list of modified parameters if the object was modified
→ Double clicking assigns the object

4 → Objects assigned from another source as the default one are highlighted
→ Only visible if merge option was chosen

5 → Only visible if merge option was chosen

### 3.3.5 Introducing the Merge Tool Context Menu

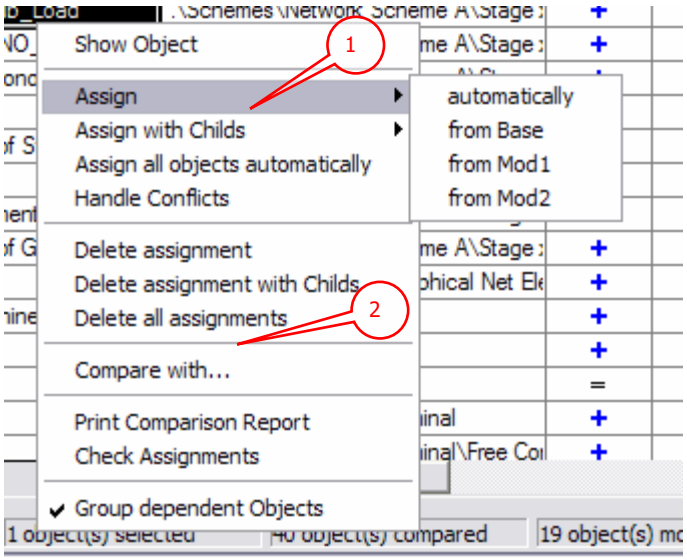


***Figure 3.9: MergeTool – Context menu***

1 Assigns selected objects and all objects contained by them

2 Option to manually align objects for comparison
→ Affected objects (and all their contained objects) are recompared

### 3.3.6 Comparing Objects with the Merge Tool

An object, which exists in the two projects, might be identified as two different objects, because of changes to the object name. To get the merge tool to identifying these objects as the same object, you can select the object in the first project and compare it individually with the project in the second project.

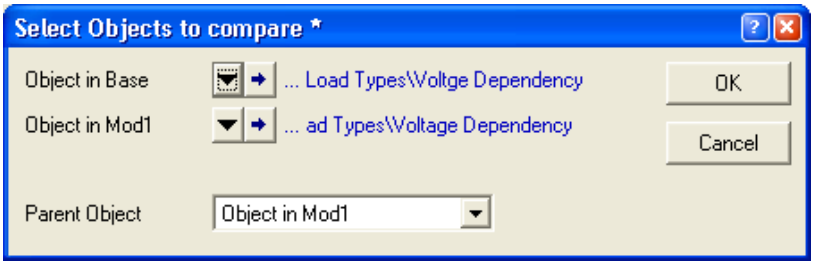


***Figure 3.10: Select objects to compare***

To compare the objects

- right-click the first object in the merge tool and select `Compare with…` Thus the object is selected as the "Object in Base" in the upcoming dialog.
- Select the object in the second project as "Object in Mod1".
- Press OK.

## 3.4 New File Format PFD for Import and Export of Project Data

For importing or exporting a project or any folder in the data base a new file format has been created: **PFD** (***PowerFactory*** Data).

The PFD format (*.pfd) is improved for handling even very large projects. The performance of the import/export has been optimized and the consumption of memory resources is much lower than with the old file format (*.dz).

All new functions available in the data base of ***PowerFactory***, e.g. time stamps and versions, are fully supported with the new PFD file format.

# 4 Models of Power System Components

## 4.1 Static Generator

The Static Generator is an easy to use model of any kind of generator, which is not rotating but static. Applications are:

- Photovoltaic Generators
- Fuel Cells
- Storage devices
- HVDC Terminals
- Reactive Power Compensations

Wind generators, which are connected with a full-size converter to the grid, can be modelled as a static generator as well, because the behaviour of the plant (from the view of the grid side) is determined by the converter:

- Wind Generators

### 4.1.1 Basic Data

On the basic date tab of the Static Generator you can choose the category of the element, enter the number of parallel generators and the ratings of one generator.

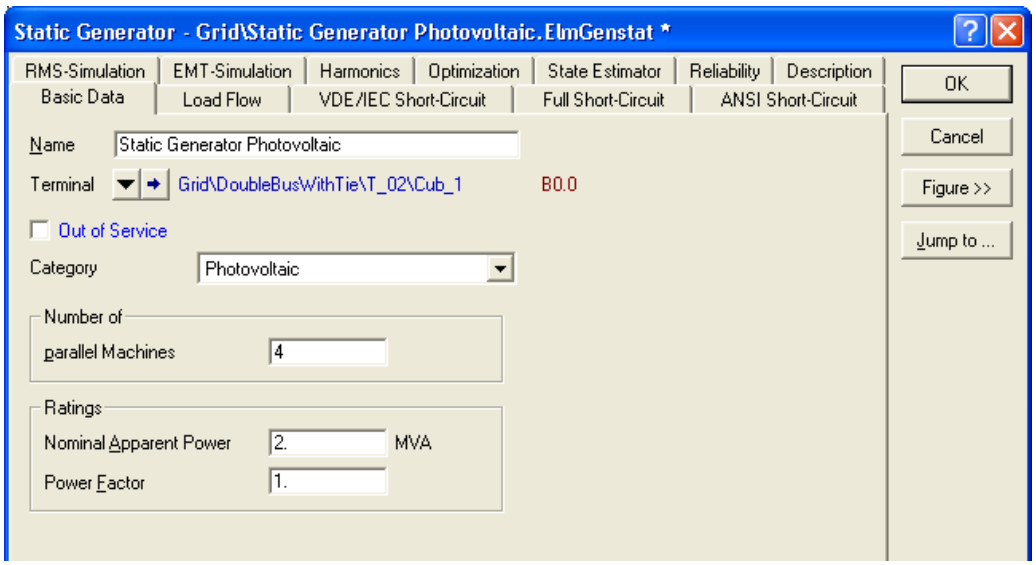


***Figure 4.1: Static Generator - Basic Data***

## 4.1.2 Load Flow Data

On the load flow tab you can define the power output: active and reactive power, or active power and voltage magnitude, or even a droop. Additionally you can specify a capability curve, which may be the whole range of the converter or a curve with the shape of a V for a min. and max. power factor for example.

$$\text{Droop}[\%] = \left| \frac{\Delta u / u_n}{\Delta Q / Q_n} \right| \cdot 100\%$$

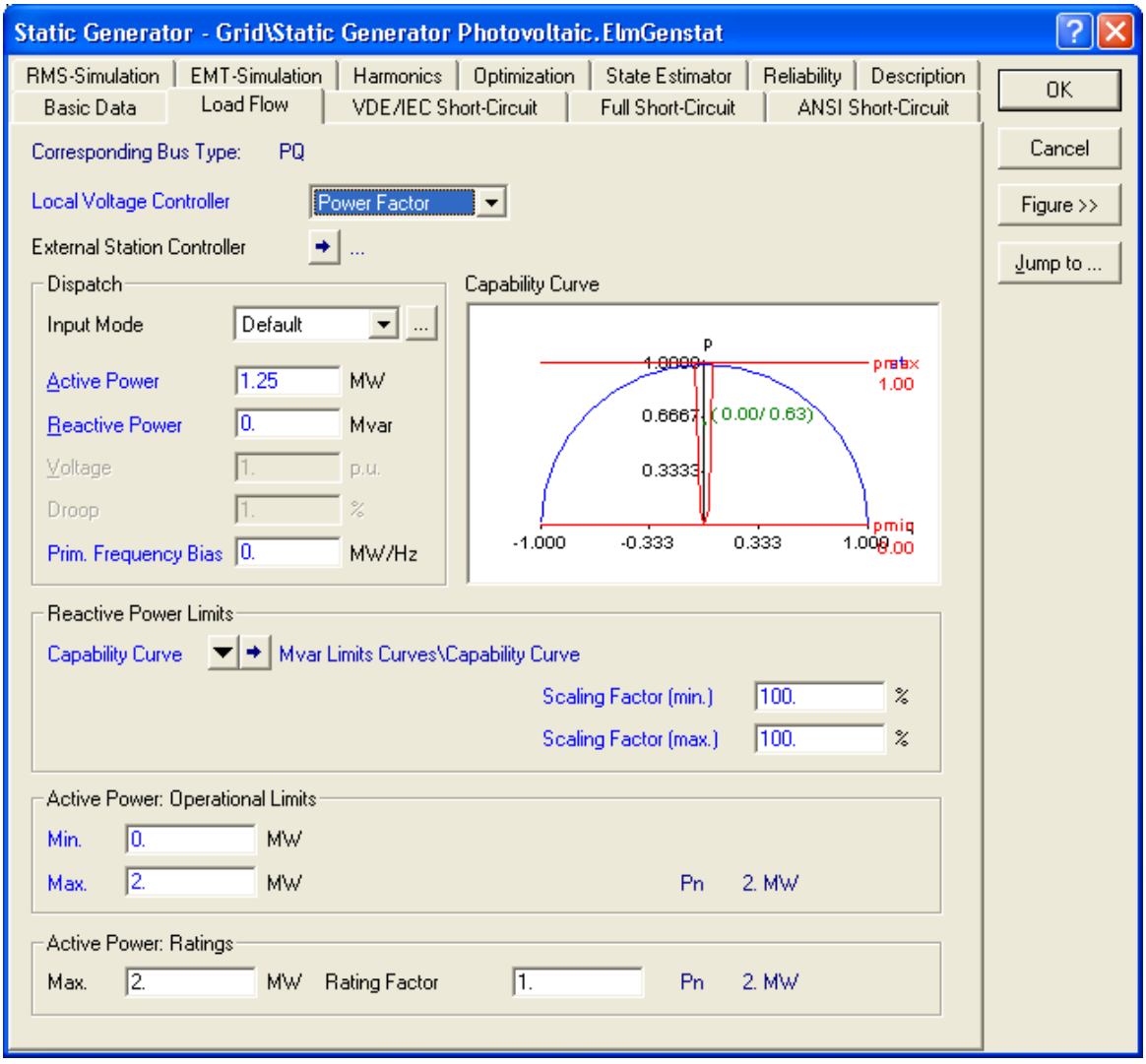


***Figure 4.2: Static Generator - Load Flow Data***

## 4.1.3 VDE/IEC Short-Circuit Data

For short circuit analysis according to IEC 60909 (VDE 0102), you can specify, whether the Static Generator shall have a contribution to the short circuit or not. In order to let the Static Generators fed into the short circuit, enable the option 'Static converter-fed drive'. With this option enabled, a Static Generator will have a contribution like a Static converter-fed drive according to IEC 60909:

- It has a contribution to $I_k''$ and to $i_p$.
- It has no contribution to $I_b$ or $I_k$.

In IEC 60909 the contribution of a Static converter-fed drive to $I_k''$ is defined by:

- $Z = \frac{1}{I_{LR}/I_{rM}} \cdot \frac{U_{rM}}{\sqrt{3} \cdot I_{rM}} = \frac{1}{I_{LR}/I_{rM}} \cdot \frac{U_{rM}^2}{S_{rM}}$
- $X = 0{,}995 \cdot Z$
- $R/X = 0{,}1$
- With $I_{RL}/I_{rM} = 3$
- The index 'rM' specifies the rating of the static converter transformer on the network side, or the rating of the static converter, if no transformer is present.

## 4.1.4 Full Short-Circuit Data

If you want to define a user-specific level for the subtransient and a transient short circuit, you can do so using the Complete Method. For short circuit calculations by the Complete Method you can enter a subtransient and a transient short circuit level, either as short circuit power or as short circuit current, and the R/X ratio (alternatively the X/R ratio). Additionally it is possible to enter values for the zero sequence impedance, for example if the Static Generator includes a transformer with earthed star point.

## 4.1.5 Optimization Data

On the optimization tab you can add the Static Generator to a Virtual Power Plant.

## 4.1.6 RMS- / EMT-Simulation Data

In time-domain-simulations the Static Generator acts similar to a PWM converter.

# 4.2 User Defined Capability Curve

The **Capability Curve objects (IntQlim)** allows the consideration of distinct minimum / maximum values of the reactive power, at different levels of active power injection. Capability curves are stored inside the '**Mvar Limits Curves**' folder in the Operational Library. Synchronous generators (ElmSym) and static generators (ElmGenstat) defined in the network model can use a pointer to a Capability Curve object from the load flow page of their edit dialogue. When a capability curve is used, the dispatch of the generator always stays within its minimum and maximum range.

### 4.2.1.1 Creating a New Capability Curve Object

To create a new generator capability curve (object of the class IntQlim), open the folder 'Mvar Limit Curves' from the Operational library, click on the 'New Object' icon ( ) and select *Capability Curve (IntQlim)*. The edit dialogue of the new capability curve pops up. Define the generation limits as described in section 4.2.1.5. Afterwards press **OK**.

Alternatively, press in the load flow page of the synchronous machine's element dialogue. Then select "User defined Capability Curve" and enter the curve as series of points in the table. Use right-click to append, delete or insert new lines etc.

### 4.2.1.2 Applying MVAr Limits Curve from Operational Library

To apply an existing generator capability curve to a generator:

- Locate the "Reactive Power Limit" section in the load flow page of the synchronous machine's or static generator's dialogue.
- Press next to "Capability Curve".
- Choose "Select" to look for a suitable curve in the "Mvar Limit Curves" folder in the "Operational library" folder.

### 4.2.1.3 Defining a MVAr Limits Curve

In the dialogue window of the capability curve, right-click within the empty fields and choose `Append rows` or `Append n rows`, in order to add the required number of rows to the table. Construct the curve as a series of points. Insert data as required for the right shape of the curve.

### 4.2.1.4 Editing a Capability Curve

The values of a capability curve can be changed at any time by double clicking on it to open the corresponding edit dialogue. Similar to circuit breaker ratings, capability curves can become time dependant by means of variations and expansion stages stored inside the Mvar Limit Curves folder.

Capability Curves are assigned using the reference from the 'Load Flow' tab of the synchronous generators. They are included in the operation scenario subsets; therefore if a capability curve is selected/reset from a generator

when an operation scenario is active, the change will be stored in the operation scenario. Once the operation scenario is deactivated the assignment/reset of the curve is reverted.

#### 4.2.1.5 Defining a Variation of a MVAr Limits Curve

Find the MVAr Limits Curves folder on the left side of a data manager. Right click on it and select *New -> Variation*. Provide a suitable name and select OK. Now right-click on the new variation and select *New -> Expansion stage*. Edit the stage and press OK.

#### 4.2.1.6 Activating a Variation of a MVAr Limits Curve

Open a Data Manager. Locate the Variation object in the Mvar Limits Curves folder of the Operational Library. Right-click on this object and select `Activate`.

# 4.3 Virtual Power Plant

Virtual Power Plants are used to group generators in the network in such a way that the total dispatched active power is set to a target value. The dispatch of each generator (variable pgini available on the Load Flow tab of the generators dialogue) is scaled according to the Virtual Power Plant rules (must run, merit of order, etc.), in order to achieve the total target value.

Virtual Power Plant objects (ElmBmu) are stored inside the 'Virtual Power Plants' folder within the Network Data directory.

## 4.3.1 Defining and Editing a New Virtual Power Plant

A new Virtual Power Plant is created by:

Multi selecting in a single line diagram or in a data browser an initial set of generators to be included in the Virtual Power Plant; pressing the right mouse button and selecting Define… --> Virtual Power Plant from the context sensitive menu.

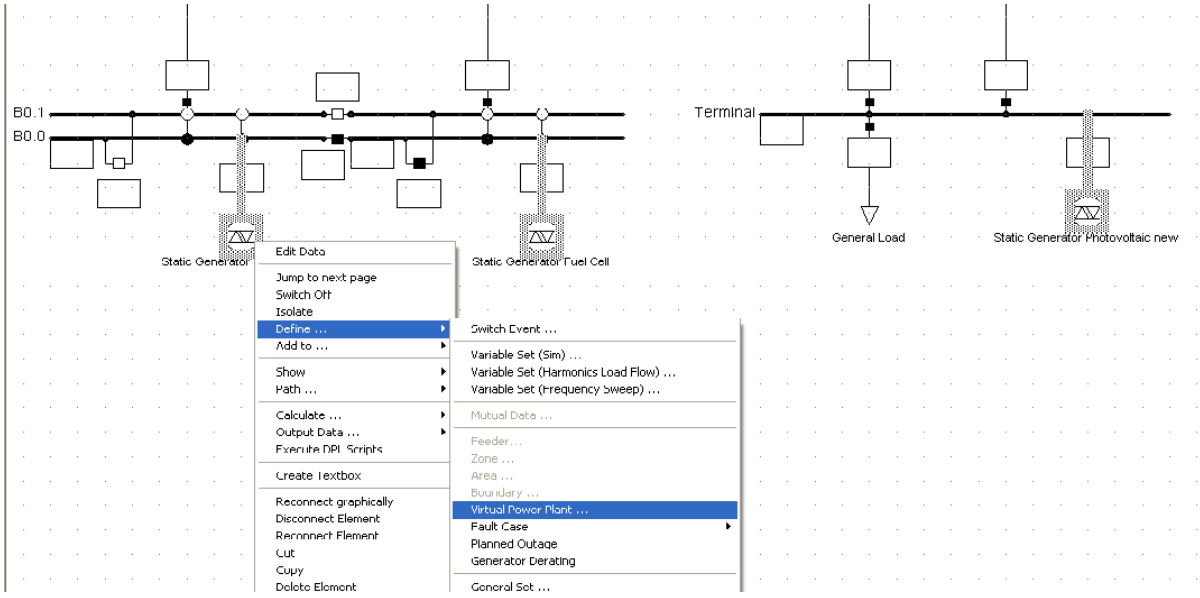


***Figure 4.3: Defining a Virtual Power Plant***

Alternatively you can create a new Virtual Power Plant by using the Data Manager:

- Open a data manager.
- Find the Virtual Power Plant folder and click on it.
- Press the icon for defining new objects .
- Select "Others".

- Then select "Virtual Power Plant (ElmBmu)" in the list box.
- Assign a suitable name to the Virtual Power Plant.
- Press OK.

The rules which determine the dispatch of the selected generators are set in the Virtual Power Plant dialogue. The total active power to be dispatched is set in the field 'Active Power'. The dispatch of the belonging generators (variable pgini from the Load Flow tab of the generator) is set by pressing the Apply button. If the 'Maximal active power sum' of the included generators (sum of the maximal active power operational limit of the generators) is smaller than the active power to be dispatched, an error message pops up. Otherwise the dispatch is set according the user defined 'Distribution Mode':

- According to merit order
  Distribution of the dispatched active power is done according to the priorities given to each generator in the Merit Order column of the 'Machines' table (this value can also be set in the Optimization tab of the generators dialogue). Lower values have higher priority. Generators with the option 'Must Run' checked are dispatched even if they have low priority (high value). It is assumed that the merit of order of all generators in the Virtual Power Plant is different. If not an error message appears after the 'Apply' button is pressed.

- According to script
  The rules for the dispatch are set in user defined DPL scripts, which are stored inside Virtual Power Plant object. To create new scripts or to edit the existing ones you must open a data browser with the 'Scripts' button.

### 4.3.2 Applying a Virtual Power Plant

Check that the active power set for the Virtual Power Plant is less than or equal to the maximum power. Press the "Apply" button.

### 4.3.3 Inserting a Generator into a Virtual Power Plant and Defining its Virtual Power Plant Properties

Generators are added to an existing Virtual Power Plant by adding a reference in the 'Optimization' tab of their edit dialogue. Notice that a generator can belong to at most one Virtual Power Plant. Define the Merit Order and must run properties as required.

You also can add a generator to a Virtual Power Plant by clicking with the right mouse button on the element in the network graphic and choose "Add to… -> Virtual Power Plant…" from the context sensitive menu.

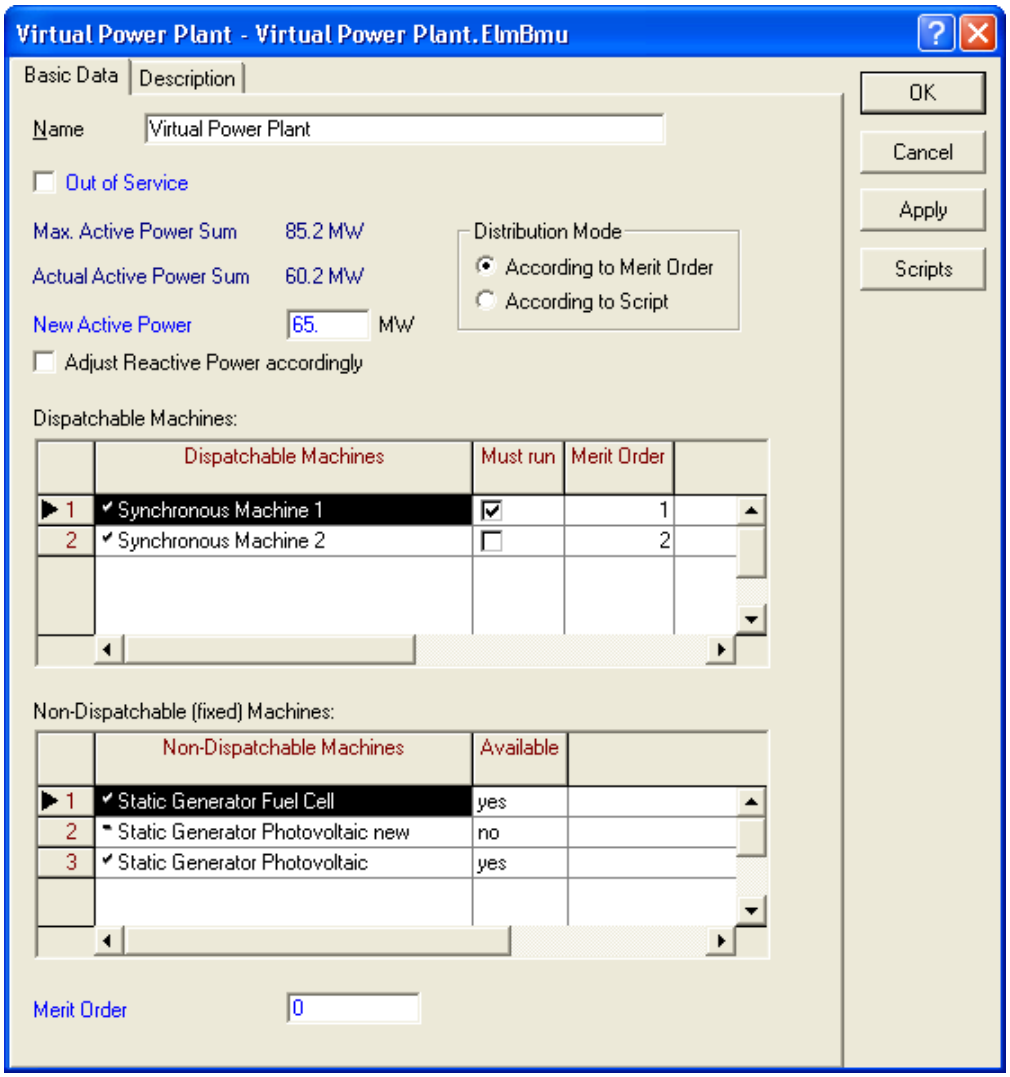


***Figure 4.4: Virtual Power Plant***

# 5 Power System Analysis Functions

## 5.1 Load Flow Analysis

This section describes the new features of the load flow calculation command of ***PowerFactory***.

### 5.1.1 DC Load Flow (linear)

In addition to the "AC" load flow calculations ***PowerFactory*** offers a so-called "DC" load flow calculation method (applied to AC systems), for fast analyses of complex transmission networks where only the flow of active power trough the branches is to be regarded. In this case the nonlinear system resulting from the nodal equations is simplified (based on the dominant relation that exists between voltage angle and active power flow in high voltage networks), in order to obtain a set of linear equations, where the voltage angles of the buses are directly related to the active power flow through the reactances of the individual models. The DC load flow does not require an iterative process and the calculation speed is considerably increased. Only active power flow without losses is considered.

### 5.1.2 Reference Bus and Balancing

If "As Dispatched" is selected in the Active Power Control field, additional options regarding the location of the reference bus bar and the power balancing method become available:

- **Reference Busbar:**
  A bus bar different than the one connecting the slack machine (or network) can be selected as reference for the voltage angle. In this case the user must specify the value of the voltage angle at the selected reference bus; which will be remotely controlled by the assigned slack machine (or network).

- **Angle:**
  User defined voltage angle for the selected reference bus bar. The value will be remotely controlled by the slack machine (external network). Only available if a Reference Busbar has been selected.

- **P-balancing:**
  If there is load (ElmLod) connected to the reference bus bar, the active power balance can be achieved by increasing/decreasing the active power demand of that load or using the reference machine.

### 5.1.3 Time Phase

Time Phases are used for Contingency and Reliability analyses.

When performing steady state reliability analyses it is important to regard the duration of contingencies, in order to determine if controlled devises such as transformer tap changers or switchable shunts are to be considered (according to their controller time constants) under the changing topological conditions. The duration of a

contingency is also important when regarding the short time thermal ratings of branch components, which depend on the loading before the fault and the duration of the contingency.

***PowerFactory*** considers the duration of contingencies by means of the option Post Contingency from the Time Phase field of the load flow command. If this option is selected (only recommended for calculations related to Contingency/Reliability analyses) the Post Contingency time (duration of contingency) must also be defined. In this case only the automatic tap changers and the switchable shunt devises whose time constants are smaller than the defined time phase are considered.

# 5.2 Short Circuit Analysis

The **Complete Method** for calculating short circuits has been upgraded:

- A more precious **Peak Current $i_p$** is calculated now, based on the accurate subtransient short circuit calculated with the complete method and the R/X ratio based on the IEC 60909.
- The **Breaking Current $I_b$** (RMS value) is calculated based on the subtransient short circuit current of the complete method and the transient short circuit current, which is calculated by the complete method as well.
- The **Peak Breaking Current $i_b$** is calculated from the RMS breaking current $I_b$ and the decaying d.c. component.
- The **Thermal Equivalent Short-Circuit Current $I_{th}$** is calculated as well.
- **Loads** can have a contribution to the short circuit current, which will be defined in the load element.

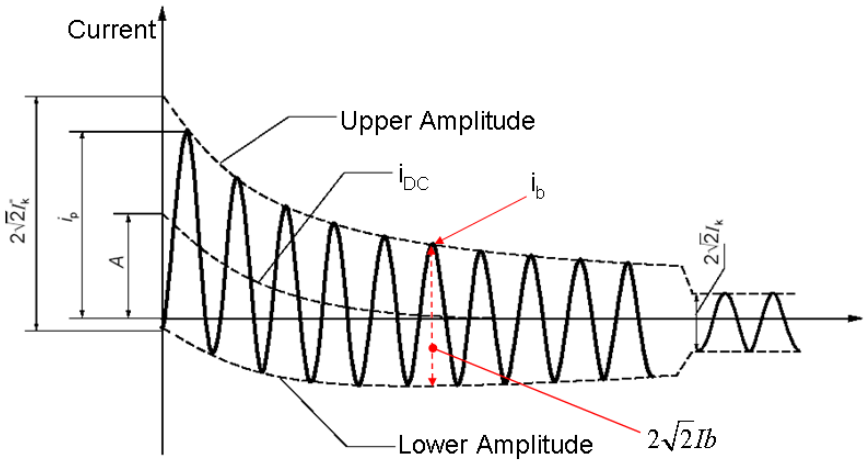


***Figure 5.1: Definition of Short Circuit Currents***

# 5.3 Contingency Analysis

The Contingency analysis has been re-engineered completely. In the following a description of the main functions is given.

## 5.3.1 Launching Contingency Analysis

The contingency analysis is a load flow analysis with some elements out of service. There is a button provided for contingency analysis in ***PowerFactory***. To see the button, choose the icon on the "Select Toolbar" (see Figure 5.2).

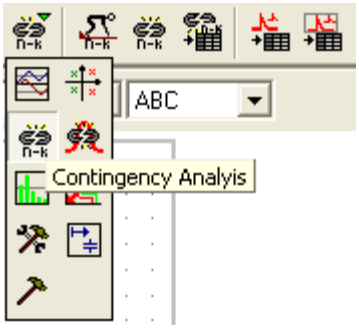


***Figure 5.2: The Contingency Analysis Toolbar***

The icon of contingency analysis, , is now visible on the first row of icons at the top of the screen.

## 5.3.2 Basic Options

**Method:**

You can select between a *Single Time Phase* Method and a *Multiple Time Phase* Method.

With the *Single Time Phase* selected you can calculate one post contingency time phase. If you select the *Multiple Time Phase* method, you can specify a list with time phases in the 'Calculation Settings' section.

**Calculation Method:**

**AC Load Flow calculation**
The contingency analysis uses an iterative AC load flow calculation to calculate the power flow per contingency case. This method is used for very precise calculations.

**DC Load Flow calculation**

The contingency analysis uses a linear DC load flow calculation to calculate the active power flow per case. This method is used for very fast calculations. Normally you will analyse the whole grid with all contingencies by DC Load Flow Calculation to find the critical contingencies. Afterwards you can analyse this critical contingencies using the AC load flow calculation.

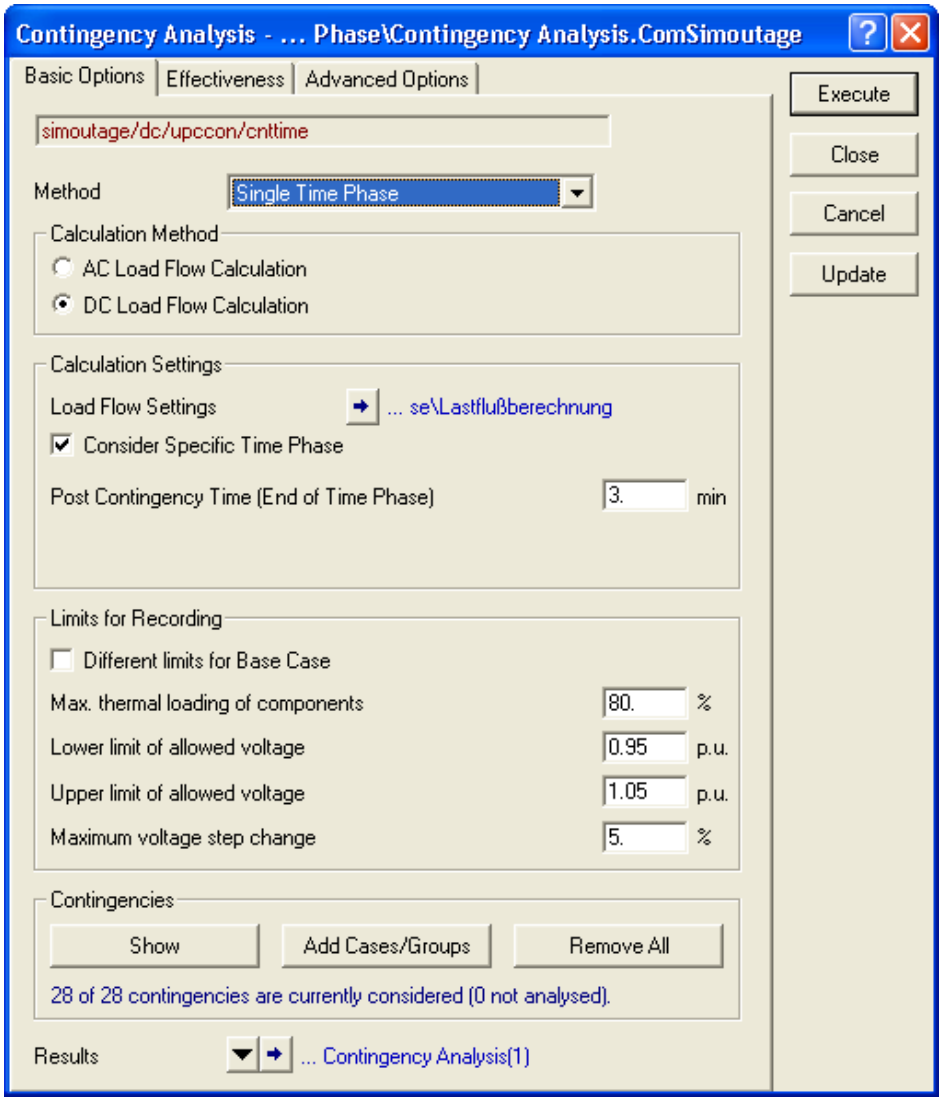


***Figure 5.3: Basic Options of the Contingency Analysis***

**Calculation Settings**

With the Single Time Phase selected you can calculate one post contingency time phase. If you don't enable the checkbox 'Consider Specific Time Phase', the time phase will be set to 0 min; this means the calculation won't consider any post fault actions. If you enable the checkbox 'Consider Specific Time Phase', you can enter the time; defined post fault actions and short time ratings will be taken into account.

If you select the method Multiple Time Phase, you can specify a list with time phases. Each time phase will be calculated automatically, taking defined post fault actions and short time ratings into account.

**Contingencies:**

The buttons in the 'Contingency' section of the dialogue are used to manage the contingency cases analyzed by the contingency analysis command:

**Add Cases**
This button is used to create contingency cases (ComOutage objects) based on fault cases, which have been previously defined in the operational library. When pressed, a data browser listing the available fault cases pops up. From the browser the user may select the target fault cases and press Ok. The corresponding contingencies are automatically created by the program. For further information about fault cases please refer to Section 5.3.6 and Section 5.3.7.

**Add Groups**
By means of this button the user can create contingency cases (ComOutage objects) based on the fault cases referred by the selected fault groups. When pressed, a data browser listing the fault groups defined in the operational library pops up. From the browser the user may select the target groups and press Ok. The corresponding contingencies (one for each fault case refereed in the selected fault groups) are automatically created by the program. For further information about fault groups please refer to Section 5.3.6 and Section 5.3.8.

**Delete All**
Deletes all the contingency cases (ComOutage objects) stored in the contingency analysis command.

## 5.3.3 Effectiveness

On the Effectiveness page you can enable to calculate the effectiveness, which generators and/or quadrature booster transformers will have on the results. This information can help you to define capable post fault actions.

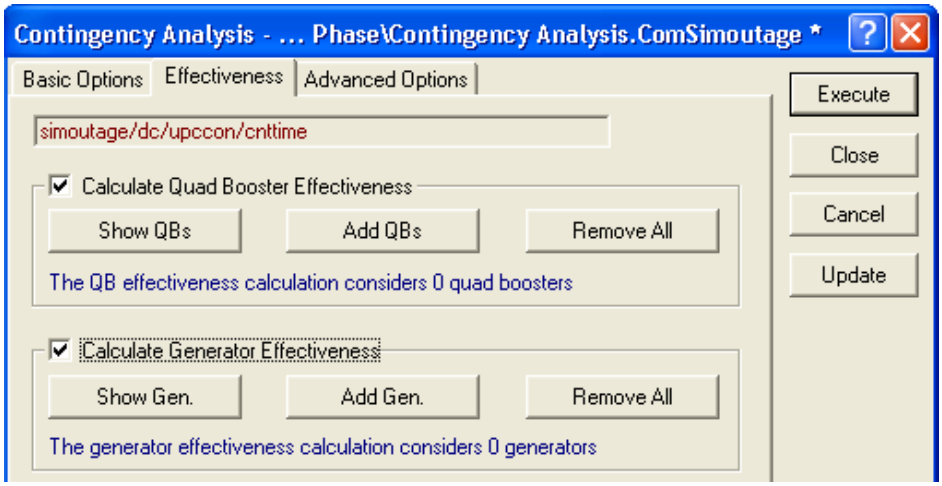


***Figure 5.4: Dialogue of Contingency Analysis showing the Effectiveness page***

## 5.3.4 Advanced Options

**Update contingencies before running a calculation**
When selected, the 'Contingency Table', the 'Boundary Table and the contingency order of all the contingency case objects (ComOutage) which are based on fault cases/groups are updated (before executing the analysis). Note that topological changes in the studied network may lead to changes in the contingency cases, therefore it is recommended to always enable this option.

## 5.3.5 Reproducing a Contingency

Press on the 'Show' Button in the contingency analysis command dialogue (see Figure 5.3) to open the list of contingencies included in the analysis. From here you can select a contingency (left-click), and mark the corresponding element in graphic using the context sensitive menu that appears by right-clicking. You can also execute contingency for each case from this list.

## 5.3.6 Browsing Fault Cases and Fault Groups

There are two types of subfolder inside the "Faults" folder in the Operational Library: "Fault Cases" and "Fault Groups".

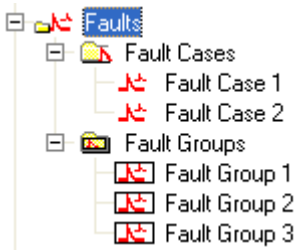


***Figure 5.5: Contents of the Faults folder in the operational library***

In order to make a new folder of each kind, click on the icon of the "Faults" folder, , press the "New Object" button, and choose whether a new "Fault Cases" or "Fault Groups" folder should be created.

The "Fault Cases" folder holds every contingency (n-1, n-2, or simultaneous) defined for the system (see section 5.3.7). On the other hand, several fault cases can be selected and stored into a "Fault Group".

## 5.3.7 Defining a Fault Case

To define a fault case for an element in the grid, select it on the single-line diagram. Then right-click and go to `Define … -> Fault Case -> n-1`. You can select several elements on the single-line diagram, in which case a fault case will be created for each in the "Fault Cases" folder. Alternatively, you can use a filter to list all the elements you would like to define outage for, select them in the list and define fault case.

If you choose n-2 instead, then fault cases will be created for the simultaneous outage of each two elements in the selection. It is also possible to indicate simultaneous outage of all the elements in the selection.

## 5.3.8 Defining a Fault Group

To define a fault group, place the cursor on the "Fault Groups" folder icon. Then press the "New Object" button. The window of a new fault group object opens where you can specify the name and add fault cases.

*Note:* When you define a fault group, and add fault cases to it, a reference is created to each selected fault case. The fault case itself sits in the "Fault Cases" subfolder. This means that if you delete the item in the group, the pointer to the fault case is deleted. The fault case itself still exists in the "Fault Cases" folder.

# 5.4 The Protection Coordination Wizard

The Protection Coordination Wizard for automatic overcurrent protection relay settings calculation has the purpose to:

- Verify that the settings (thresholds, time delays and curve shapes) of the overcurrent devices satisfy the requirements to achieve the protection of the circuit respecting the selectivity constrains and guarantying the "normal operation" of the system.

- Calculate the settings (thresholds, time delays and curve shapes) to satisfy protection, selectivity and "normal operation"

It's possible to run the verification process without running the calculation process. The calculation process is using the verification phase to validate the results and generate a report of the achieved results.

The Protection Coordination Wizard has the ability to verify/calculate the selectivity for each protective device using the settings of one phase inverse element, two phase definite time elements, one phase ground inverse element and two ground definite time elements. To protect the system the rules implemented in the wizard are calculating the relay settings of one phase inverse element, two phase definite time elements and one ground time definite element.

The Protection Coordination Wizard requires that protective devices have been created on each side of a line or of a transformer. Motors, generic loads, capacitors must be protected by a protective device located on the motor, generic load, capacitor feeder itself.

Please keep in mind that the coordination process is flexible but cannot manage any possible "circuit" configuration: some of them cannot be protected in a perfect way due to the circuit characteristics and to the protective device characteristics.

**Example:**

A relay protecting two transformers in parallel, the relay trip threshold should be at least two times the single transformer rated current. To manage the CT errors and the relay measurement error a 110% (or greater) safety factor is added to the threshold. The threshold value we obtain doesn't guarantee to fully protect the single machine. So it appears clear that not always coordination process is able to achieve a perfect coordination of the protective devices and protection of the protected items. Many times the results we get are an acceptable compromise between the protection and coordination needs using the available protective devices characteristics. In this case a full report showing the current ranges where the coordination or the protection isn't achieved will be made available.

## 5.4.1 Starting the Protection Coordination Wizard

Before you can use the Protection Coordination Wizard you have to:

- Define protection devices in the grid.

- Define a feeder for the section of the grid, in which you want to ccordinate the protection devices.

With these elements available in your grid, you can use the Protection Coordination Wizard. To start the wizard, either:

- Select the Protection toolbar in the main icon bar of PowerFactory.
- Press the 'Protection Coordination Wizard' button as shown in Figure 5.6.

or:

- Click with the right mouse button on an element in the single-line diagram, which is part of the feeder, i. e. the part of the grid, for which you want to coordniate the protection devices.
- Select *Calculate -> Protection Coordination Wizard* from the context sensitive menu as depicted in Figure 5.7.

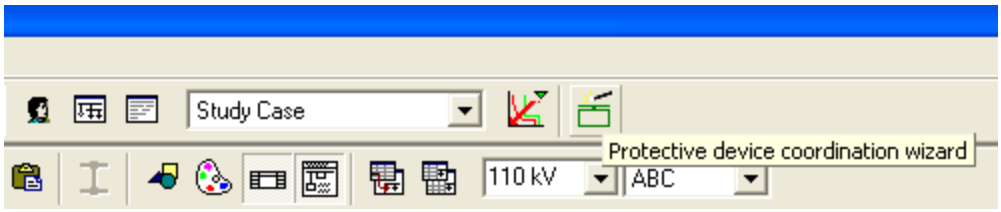


***Figure 5.6: The Protection Coordination Wizard button in the Protection toolbar***

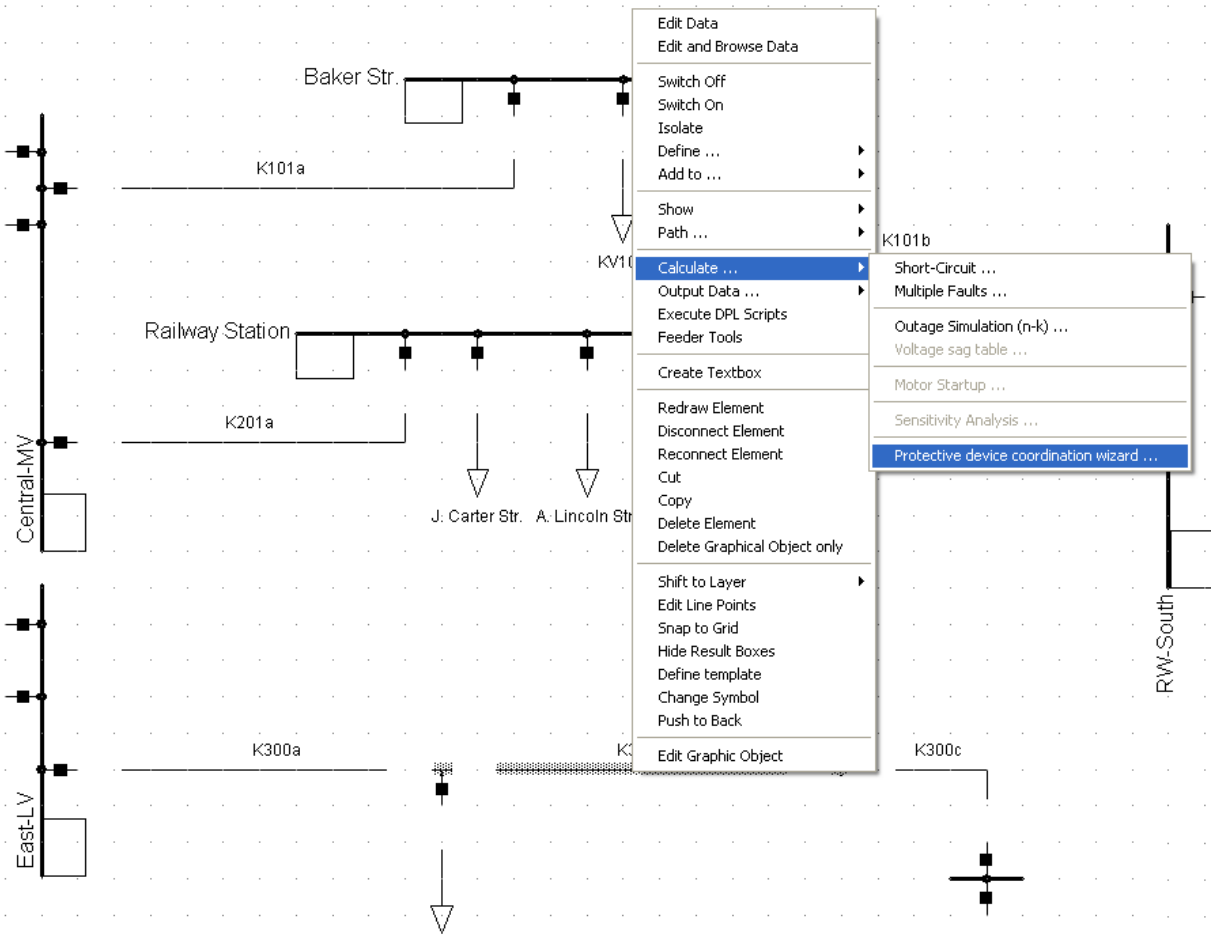


***Figure 5.7: Starting the Protection Coordination Wizard from the context sensitive menu***

The dialogue of the Protection Coordination Wizard pops up (see Figure 5.8). Configure the Coordiniation Wizard for meeting your requirements. For detailed information, please refer to the PowerFactory V14.0 User's Manual. Afterwards press the Execute button to run the coordination process.

## 5.4.2 The Dialogue Window of the Protection Coordination Wizard

Normally you just have to select the options on the 'Basic Options' tab. Advanced users may use the 'Configuration' tab as well. On the 'Output' tab you can select the output format.

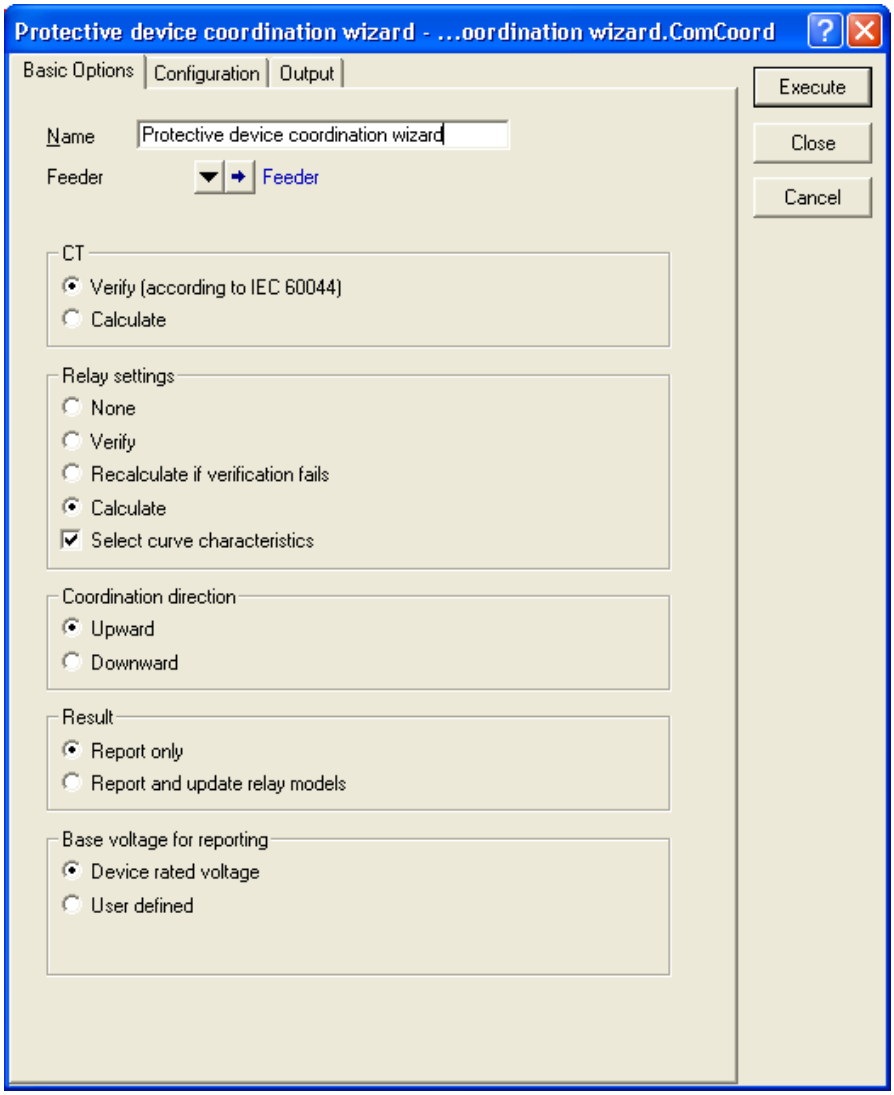


***Figure 5.8: The Protection Coordination Wizard dialogue - Basic Options***

# 5.5 Network Reduction

The typical application of network reduction is a project where a specific network has to be analyzed but this network cannot be studied independent of a neighboring network of the same or of a higher or lower voltage level. In this case it is one option to have both networks modeled in detail for the calculation. There however may be situations when it is not desirable to perform the studies with the complete model. This is the case for instance when the calculation times would increase significantly or when the data of the neighboring network should not be published in detail. In these cases it is good practise to provide an representation of the neighboring network, which contains the interface nodes (connection points) which may be connected by equivalent impedances and voltage sources.

The network reduction algorithm produces an equivalent representation of the reduced part and calculates its parameters. The equivalent will be valid for both load-flow and short-circuit calculations, even for asymmetrical faults (single phase faults for example).

## 5.5.1 Executing the Reduction Process

The cut through the grid, which devides the network into a part that shall remain in its original detailed representation (the retained grid) and a part that is to be reduced (i. e. shall be represented by a simplified equivalent grid), is defined by means of a Boundary element (ElmBoundary). A boundary element is substantially a set of cubicles, each one defined with a given orientation to distinguish the two portions of the network separated by the boundary as "interior" and "external". The cubicles in the Boundary Element have to be orientated in order to have the part of the grid, which shall be reduced, as "interior".

To reduce the network, please proceed as follows:

- The Network Reduction function can keep the original data. It will destroy the original data only, if the option for this is set accordingly (see section 5.5.2.2). However, if you want to be absolutely sure to avoid any loss of data, even when accidentally selecting the option, which will delete the original grid during the reduction procedure, please first either
    - make a copy of the whole project and paste/store it with a name different from the original project, or
    - export the project as *.dz- or *.pfd-file (for information about exporting of data please refer to Section 8.1.4: Exporting and Importing of Projects), or
    - activate the project and create a new Version of the project. For information about Versions please refer to Section 3.1.
- Activate the base Study Case. This loads the original network.
- If you have migrated your Project from PowerFactory version 13.2 or previous, please make sure that either there is a Variations folder in your Project now (located inside the Network Model folder) or there are already existing System Stages (located inside the Grid folders). Concerning this point, please refer to Section 5.5.2.2 (Outputs).

- Define the Boundary, necessary to split the grid in the part that shall be reduced and the part that shall remain in its detailed representation. Make sure, that the Boundary splits the network into two regions by using the Check Split button of the Boundary dialogue. For more information about boundaries, please refer to Section 2.3.1.6 (Boundaries).

- Select the 'Additional Tools' from the main icon bar.

- Press the 'Network Reduction' button from the Additional Tools icon bar (Figure 5.9). This opens the dialogue for the network reduction.

- Choose the settings according to Section 5.5.2 (Options of the Network Reduction).

- Please click on the Execute button to start the reduction procedure.

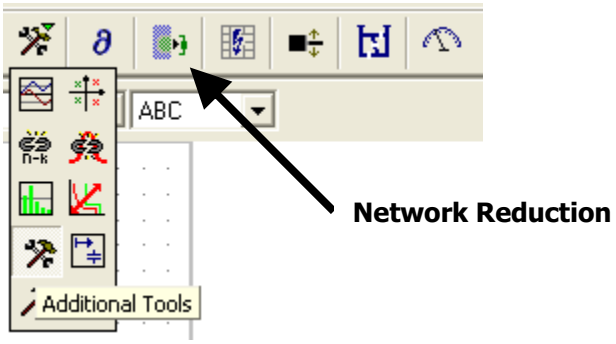


***Figure 5.9: The Network Reduction button in the Additional Tools icon bar***

Depending on the option you select on the 'Outputs' tab (section 5.5.2.2: Outputs) the procedure of the network reduction may automatically create a new variation / system stage representing the original grid. If the original system is represented with multiple grids (or system stages of multiple grids), a new system stage will be created in each one. In the new system stage(s) the part of the grid, which shall not be reduced remains in full representation, whereas the part that shall be reduced is erased and the new simplified grid representation is added, with the connections to the other part of the grid (i. e. to the part which is not reduced). The new system stage(s) will therefore represent the combined grid (retained grid and reduced equivalent).

The new system stages will be activated automatically in the active study case.

In case one or more single line graphic diagrams were available in the system stage(s) with the original grid, these graphics will be available also in the new system stage(s) with the combined (partly retained and partly reduced) grid. The first time the new study case will be activated (automatically at the end of network reduction procedure) and these graphics are shown, the elements of the part of the grid that has been reduced (in any of them were shown) appear in grey colour, as "ghost" elements. Deactivating and re-activating the project will make them disappear permanently (they were graphic elements only, and had no corresponding elements in the data base in the new system stage(s)).

The elements of the equivalent grid (equivalent branches, equivalent shunts, equivalent injections...) are stored in the data base but have no graphic image for the moment. You can easily draw them making use of the PowerFactory tool "Draw Existing Net Elements".

## 5.5.2 Options of the Network Reduction

In this section the options of the network reduction available on the different tabs of the command dialogue are explained.

### 5.5.2.1 Basic Options

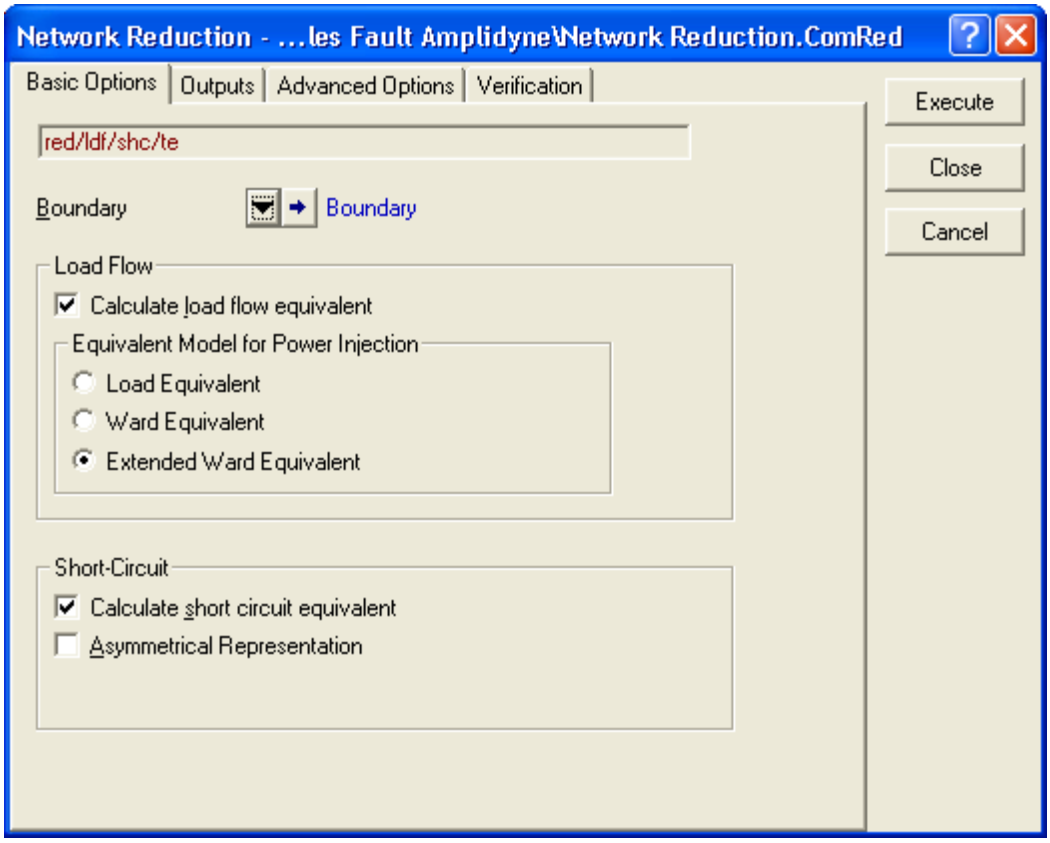


***Figure 5.10: Network Reduction - Basic Options***

**Boundary**

The part of the grid, which shall be reduced, has to be defined by a boundary. Since in the boundary folder many boundaries could be defined, the user has to select the boundary corresponding to the cut, which devides of the original grid, into the part that shall be reduced, and the part that shall remain in full representation. Only one boundary can be used in the network reduction calculation. For more information about boundaries, please refer to section 2.3.1.6 (Boundaries).

**Calculate load flow equivalent**

With this option enabled, the load flow equivalent will be calculated. If you disable this option, the load flow equivalent will not be created. Normally this option is enabled.

**Equivalent model for power inject**

The load flow equivalent is composed of mutual impedances among boundary nodes and power injections (and shunt impedances) at boundary nodes. Such a power injection could be represented by different models. For the load flow equivalent there are three options (models), which you can choose:

**Load Equivalent:** a load demand

**Ward Equivalent:** an AC voltage source which is configured as Ward Equivalent

**Extended Ward Equivalent:** an AC voltage source which is configured as Extended Ward Equivalent

**Calculate short-circuit equivalent**

With this option you specify, whether the short circuit equivalent shall be calculated (option enabled) or not (option disabled). Currently, only the 'complete' short circuit calculation method is supported.

**Asymmetrical Representation**

With this option you specify, if an unbalanced short circuit equivalent shall be created.
If this option is disabled, only a balanced short circuit equivalent will be created, valid for the calculation of 3-phase short circuits.
If this option is enabled, an unbalanced short circuit equivalent is created as well, valid for the calculation of single phase and 2-phase short circuits. That means the network representation must include zero sequence and negative sequence parameters, otherways the unbalanced calculation cannot be performed.

### 5.5.2.2 Outputs

On the 'Outputs' tab you can specify, if the parameters of the reduced grid shall be reported only, or if the reduced grid shall be stored in a new variation.

**Calculation of Parameters only**

The equivalent parameters are calculated and reported, no new variation will be created

**Create a new Variation for reduced network**

The equivalent parameters are calculated and a new variation will be created automatically to store the reduced network representation.

**Reduce Network without Creating a new Variation**

The reduced network will be stored directly in the grid folder inside the network data folder. No variation will be created. The part of the grid to be reduced will be deleted and replaced by its reduced representation.
If you don't want to lose the data of the original grid, you should save the data before executing the network reduction with this option. To safe the data either create a revision manually, create a version of the project, make a copy of the whole project, or export the project.

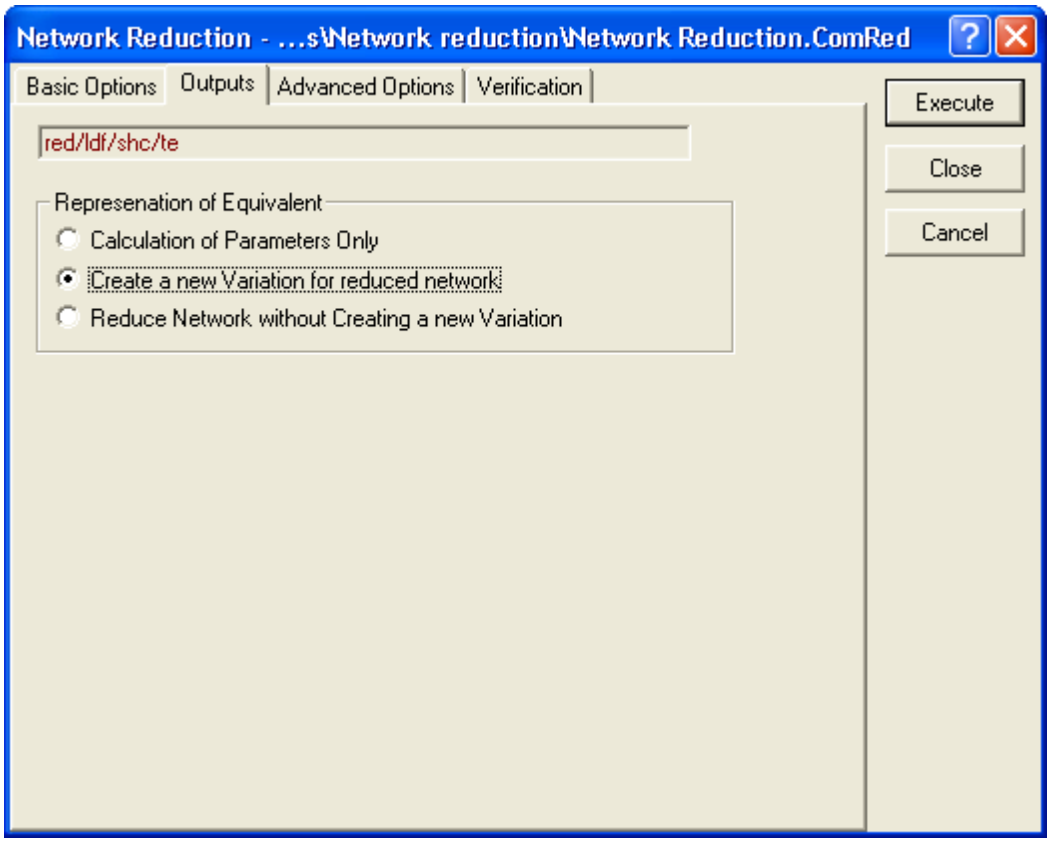


***Figure 5.11: Network Reduction - Outputs***

### 5.5.2.3 Advanced Options

**Mutual Impedance**

You can enter the value for the maximum equivalent branch impedance to be considered. The network produce will create the equivalent, which will be composed, among the other elements, of equivalent branches that will join each couple of boundary nodes (a boundary node will be identified for each boundary cubicle). The number of these branches will be therefore N (N-1)/2, where N is the number of the boundary nodes: this number can be very high in case of many boundary nodes. It frequently occurs that some (or many) of these equivalent branches have a very big impedance value, and therefore the power flows of them are negligible: they could be assimilated to an open branch. Therefore the user is given the possibility to define an impedance limit value, over which the branches will be neglected (not represented) in the reduced network equivalent.

**Calculate Equivalent Parameters at All Frequencies**

With this option you can enable or disable the calculation of frequency related parameters. By default the short circuit equivalent parameters are calculated at all frequencies relevant for short circuit analysis (equivalent frequencies for calculating the d.c. component of the short circuit current):

- f = fn
- f / fn = 0.4
- f / fn = 0.27
- f / fn = 0.15
- f / fn = 0.092
- f / fn = 0.055

$f_n$ is the nominal frequency of the grid (usually 50 Hz or 60 Hz).

If only the transient and sub-transient short circuit currents are concerned, the frequency related parameters can be skipped by uncheck this option.

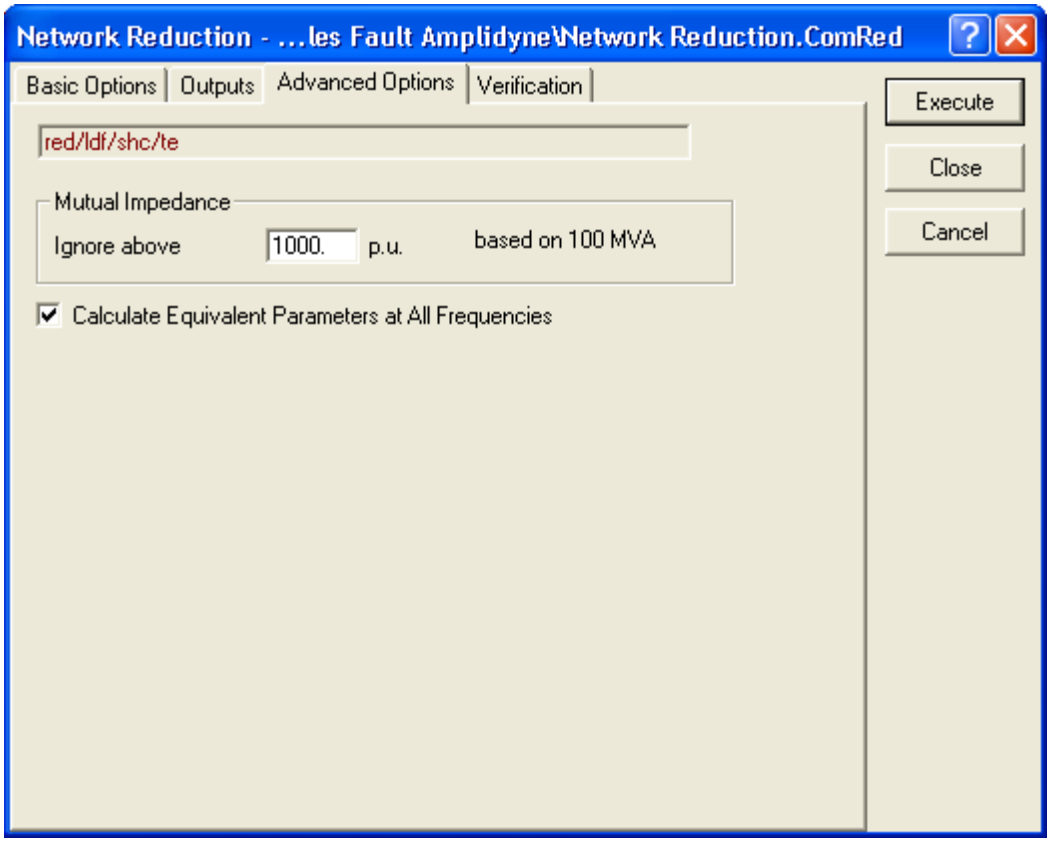


***Figure 5.12: Network Reduction - Advanced Options***

### 5.5.2.4 Verification

**Check equivalent results**

If the option 'Check load flow results after reduction' is enabled, the load flow results at the boundary nodes will be checked against the results of the original network. A warning message will be given if the results do not fit.

**Check Deviation of Working Point**

If the option 'Save Original Operation Point to Result File' is enabled, the operation point where the network reduction takes place will be automatically saved to result files. Two results file will be created:

- LdfResultforNR.ElmRes: voltage magnitude and angle of all boundary nodes
- ShcResultforNR.ElmRes: short circuit level at all boundary nodes, including $I_k''$ (Ikss), $I_k'$ (Iks), $i_p$ (ip), $i_b$ (ib), $I_b$ (Ib), $X_b/R_b$ (XtoR_b), and X/R (XtoR).

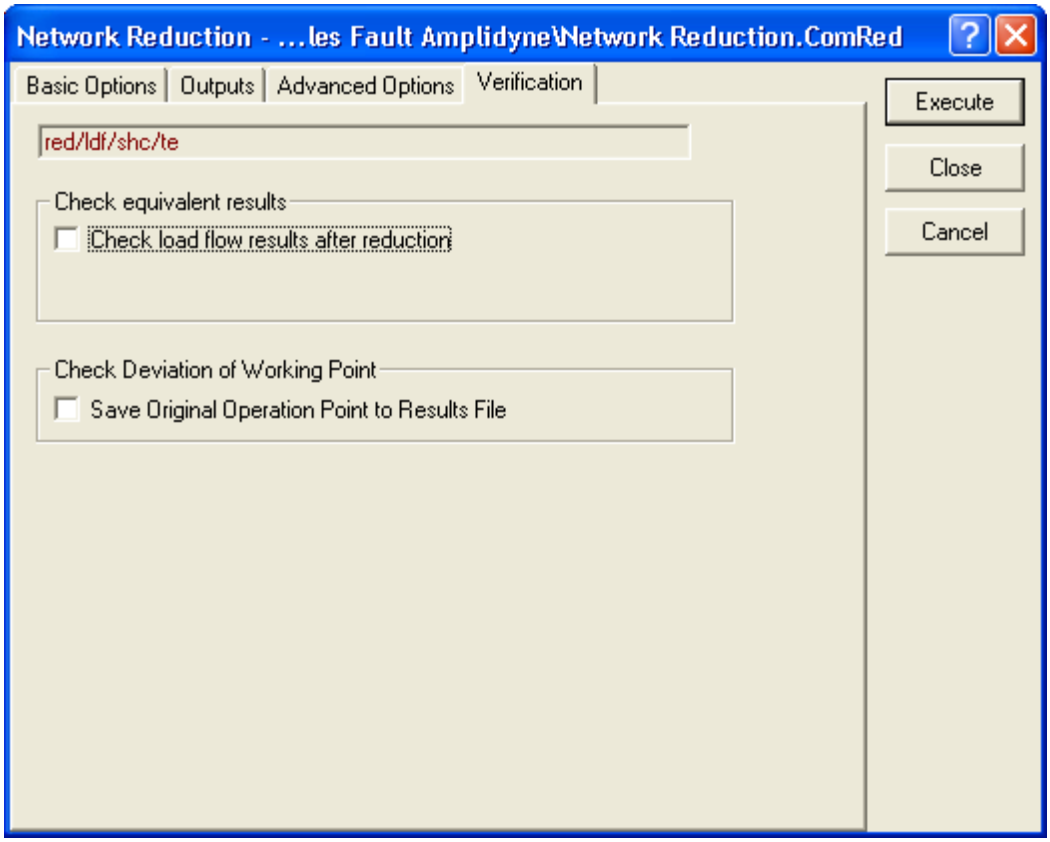


***Figure 5.13: Network Reduction - Verification***

## 5.5.3 Technical Background

For a better understanding of the Network Reduction function, its procedure is explained in the following.

### 5.5.3.1 Network Reduction for Load-Flow

The Network Reduction calculation for load-flow is an algorithm procedure based on sensitivity matrixes. The basic idea is that the sensitivities of the equivalent grid, measured in the connection points with the retained grid, must be equal to the sensitivities of the grid that has been eliminated. This means that for a given (virtual) set of $\Delta P$ and $\Delta Q$ injection in the branches, from the retained grid to the grid to be reduced, the resulting $\Delta u$ and $\Delta \varphi$ (voltage magnitude and voltage phase angle variations) in the Boundary nodes must be the same with the equivalent grid as the ones that would have been obtained with the original grid.

### 5.5.3.2 Network Reduction for Short-Circuit

The Network Reduction for short-circuit is an algorithm procedure based on nodal impedance / nodal admittance matrixes. The basic idea is that the impedance matrix of the equivalent grid, measured in the connection points with the retained grid, must be equal to the impedance matrix of the grid to be reduced for the rows and columns that correspond to the Boundary nodes. This means that for a given (virtual) additional $\Delta I$ injection (variation of current phasor) in the Boundary branches, from the retained grid to the grid to be reduced, the resulting $\Delta u$ (variations of voltage phasor) in the Boundary nodes must be the same with the equivalent grid as the one that would have been obtained with the original grid.

This must be valid for positive sequence, negative sequence, and zero sequence cases, if these ones are to be considered in the calculation (unbalanced short-circuit equivalent).

### 5.5.3.3 Handling of Slack Bus

If the slack bus is located in the Grid to be reduced, a neighbourhood of this slack will be automatically selected. This neighbourhood will be excluded from the Grid to be reduced. That means the neighbourhood of the slack bus will remain after the Network Reduction procedure. The neighbourhood is searched from the slack element towards each connection until a non-zero impedance element is passed.

# ANNEXES

## Annexes

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